IMPROVING MAIZE BY QTL MAPPING, AGRONOMIC PERFORMANCE AND BREEDING TO REDUCE AFLATOXIN IN TEXAS

A Dissertation

by

KERRY LUCAS MAYFIELD

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 2011

Major Subject: Plant Breeding

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Approved by:

Co-Chairs of Committee,	William L. Rooney
	Seth C. Murray
Committee Members,	Thomas Isakeit
	Gary Odvody
Head of Department,	David D. Baltensperger

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ABSTRACT

Improving Maize by QTL Mapping, Agronomic Performance and Breeding to Reduce Aflatoxin in Texas. (May 2011)

Kerry Lucas Mayfield, B.S., Texas Tech University;

M.S. Texas A&M University

Co-Chairs of Advisory Committee, Dr. William L. Rooney
Dr. Seth C. Murray

Aflatoxins are potent carcinogens produced by the fungus *Aspergillus flavus* Link:Fr and are a significant preharvest problem in maize production in Texas, the southern US, and subtropical climates. Several sources of maize germplasm are available which reduce preharvest aflatoxin accumulation, but many of these sources lack agronomic performance for direct use as a parent in commercial hybrids. Tropical germplasm is a source of both resistance to aflatoxin accumulation resistance and agronomic performance traits. The goal of this study was to investigate germplasm for traits to reduce preharvest aflatoxin accumulation. The specific objectives of this research were: 1) to validate QTL estimates previously identified in lines *per se* and estimate new QTL associated with reduced aflatoxin accumulations and agronomic traits; 2) to evaluate agronomic characteristics of selections from a RIL population in testcrosses at multiple locations across Texas; and (3) to release agronomically desirable germplasm sources with reduced risk to preharvest aflatoxin accumulation.

A total of 96 QTLs were detected across fourteen measured traits using an RIL population of 130 individuals in testcross hybrids evaluated in five environments.

Three QTL detected in *per se* analyses were also detected in hybrid testcrosses. Previously unreported QTL were detected on chromosomes 3, 4, 8 and 9.

Within each of the two years, neither subset of the RIL testcross hybrids produced grain yields equal to commercial hybrid checks in these trials, but one testcross in 2008 produced grain yield within 10% of commercial check hybrids and in 2009, five RIL testcrosses produced grain yield within 17% of the commercial check hybrids. Although RIL testcrosses did not yield more than the commercial checks, they will be a source of germplasm for reduced aflatoxin.

Improved sources of maize germplasm lines Tx736, Tx739, and Tx740 have been selected for adaptation to southern US and Texas growing environments with traits that reduce aflatoxin accumulation. Each of the lines in testcross accumulated significantly fewer aflatoxins than commercial hybrids in the trial.

DEDICATION

To my wife, Chyrel, and son, Robert; thank you for putting up with me through the end of this. I love you both. To my mother, Paulette; thank you for pushing softly and encouraging me early through school and allowing me to grow. To my father, Butch; thank you for teaching me the value of hard work early in my life.

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I would like to thank my committee members Dr. Rooney, Dr. Murray, Dr. Isakeit and Dr. Odvody for helping and pushing to finish this project. I have learned a lot from each of you and look forward to future collaborations.

I would like to thank the funding sources for funding this research, Texas Corn Producers Board, USDA and Texas AgriLife Research. Without this funding, this research and knowledge would not have come.

Too many people were involved in collecting data and assisting in the breeding nurseries to be mentioned. Those in particular included Jeff Remmers, Beto Garza, Martin Barrera, Lori Gregg, John Drawe, Dale Herrington and Keith Sage. The Crop Testing Program at Texas AgriLife Research was invaluable in collecting off station yield data and many thanks go to them.

I would also like to thank Dr. Baltensperger, Department Head, Department of Soil and Crop Sciences, for allowing me to continue in the Corn Breeding and Genetics program for the time prior to Dr. Murray's arrival at Texas A&M.

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INTRODUCTION

Aflatoxins produced by *Aspergillus flavus* Link:Fr are a potent carcinogen that causes liver cancer (Castegnaro and McGregor, 1998). *A. flavus* was first identified as a problem in 1961 with the mass death of turkeys consuming contaminated peanut (ground nut) meal in Great Britain (Detoy et al, 1971). While the fungus can infect many plant species, the aflatoxin it produces is a common problem in ground nuts, tree nuts, cotton and maize. Currently, preharvest aflatoxin contamination of *Zea mays* L. (maize) is a chronic problem across the southern U.S, with losses since 1990 in Texas totaling more than $75 million (USDA RMA, 2010). Crops contaminated with aflatoxins are regulated by the U.S. Department of Agriculture; contamination concentrations in the U.S. for human consumption and interstate commerce must not exceed to 20 ng g^{-1}, while concentrations up to 300 ng g^{-1} are allowed for adult cattle feed (US FDA, 2010).

Much effort has been exerted to reduce levels of contamination through various methods, including breeding germplasm with lowered susceptibility (Williams et al, 2008; Betrán et al, 2005), developing agronomic practices to lower susceptibility (Widstrom, 1996), and using atoxigenic strains of *A. flavus* as a biological control (Cotty, 1994; Atehnkeng et al, 2008). It is likely that all three of these approaches and others will be needed to effectively reduce or eliminate preharvest aflatoxin accumulations in maize.

This dissertation follows the style and format of Crop Science.

Complete genetic resistance to preharvest aflatoxin accumulations in maize has not been identified. Although varying degrees of genetic resistance have been reported in some germplasm (Williams et al, 2008), none of these germplasm have exhibited suitable agronomic qualities to be used directly in a commercial product (Scott and Zummo, 1990; Williams and Windham, 2001). Several quantitative trait loci (QTL) have been identified in different sources for reducing preharvest aflatoxin accumulations (Brooks *et al*, 2005; Bello *et al*, 2007; Warburton *et al*, 2009); however, no genes have yet been expressly identified that condition total resistance. Maize grown in tropical and subtropical areas has been identified as potential germplasm sources for genetic resistance of preharvest aflatoxin accumulations (Betrán et al, 2006a). Many accessions from these areas exhibit traits not commonly found in "corn belt" maize of the Mid-western US, including longer and tighter husks with ear tip coverage (Betrán *et al*, 2006a), kernel texture (Betrán *et al*, 2006b), altered protein composition (Brown *et al*, 2001) and altered lipid composition (Guo *et al*, 1995). Environmental factors such as drought stress and high soil temperature are also linked to increased aflatoxin accumulations (Payne, 1992; Hill *et al*, 1983); thus, germplasm adapted to these stresses should contribute to reducing aflatoxin accumulations.

The objectives of this project were to: 1) evaluate recombinant inbred lines (RIL) to confirm and detect QTL for reduced aflatoxin accumulations and agronomic desirability in hybrid testcrosses, 2) evaluate a subset of the RIL hybrids for agronomic qualities and 3) to release several sources of maize germplasm for reducing preharvest aflatoxin accumulations, contingent upon documented reductions.

CONFIRMATION OF QTL FOR REDUCING AFLATOXIN IN MAIZE TESTCROSSES

INTRODUCTION

Aflatoxins, secondary metabolites produced by the fungus *Aspergillus flavus* Link:Fr, are classified as group 1 carcinogens (IARC, 2002) that have been demonstrated to cause liver cancer (Castegnaro and McGregor, 1998). Aflatoxin enters the human and animal food stream via contamination of many common food and cereal crops; it is most prevalent in production years which are hot and dry in preharvest accumulation and with high moisture during storage. Pre-harvest aflatoxin is a chronic problem in *Zea mays* (maize)crop production under drought stress conditions resulting in severe economic losses in the southern United States and throughout the world (Wu, 2006; USDA RMA, 2009). Because of the toxicity and prevalence of aflatoxin, the United States Food and Drug Administration limits the allowable amount of aflatoxin contamination crops. For corn, aflatoxin levels below 20 ng g^{-1} are acceptable in food grain; levels between 20 and 300 ng g^{-1} may be used for different livestock feeds and above 500 ng g^{-1} the grain must be destroyed (US FDA, 2010; OTSC, 2010).

Complete genetic resistance to preharvest aflatoxin accumulations in maize has not been identified and commercially available maize hybrids have yet to exhibit adequate levels of resistance to aflatoxin accumulations (Windham and Williams, 1999; Abbas et al, 2002; Abbas et al, 2006). Transgenic efforts in reducing lepidopteron insects, such as Bt genes, have inconsistently reduced, but not eliminated, aflatoxin accumulation, as insects are only one potential mode of entry (Odvody and Chilcut, 2002 and Williams et al, 2002). Efforts to breed for reduced aflatoxin accumulations in maize have identified several associated traits including: hard kernel texture, long tight husk coverage and later maturity (Odvody et al, 1997; Betrán and Isakeit, 2004). Betrán et al (2004) found flowering time is strongly correlated to aflatoxin accumulations (r=-0.59); hybrids which flowered earlier accumulated more aflatoxins in Texas. This was due in part to earlier maturing hybrids being selected to have short and open husks needed for dry down in short season environments (Betrán et al, 2004).

Several sources of sub-tropical, tropical and some temperate germplasm have been identified that exhibit traits correlated with reduced aflatoxins in maize (Betrán *et al*, 2002; Williams and Windham, 2001; Williams and Windham, 2006; Menkir et al, 2008). Germplasm sources associated with reducing aflatoxin accumulation, however, are generally unadapted and lack adequate agronomic performance to be used directly in commercial hybrids (Abbas et al, 2002).

Resistance to aflatoxin contamination has been reported as having a genetic component with moderate to low heritability (Walker and White, 2001: Campbell and White, 1995 and Warburton et al, 2009). Betrán et al (2005) suggested that selection for agronomic traits related to reducing aflatoxin accumulations with high heritabilities may allow decreased susceptibility to be more easily selected. Evaluation of the impact of an agronomic trait on aflatoxin accumulation has been limited to traits which directly affect fungal introduction and development, e.g. kernel texture, husk coverage and ear rot. Even though it would appear that improving those traits with high correlation with aflatoxin accumulation and high heritability would aid in improving a reduction in aflatoxin, Robertson et al (2005) suggested reductions in aflatoxin may not be obtained.

The low heritability of aflatoxin contamination is caused by low repeatability (experimental error) and genotype by environment interactions which often are severe (Robertson, et al, 2005). To reduce genotype by environment interaction, trials to detect QTL for reduced aflatoxin are planted in multiple environments which results in more accurate heritability estimates, QTL estimates, and QTL repeatability (Paul et al, 2003; Brooks et al, 2005; Bello, 2007; Warburton et al, 2009).

Although there are many traits that are correlated with aflatoxin resistance, there have been very few studies that have genetically mapped variation for these secondary traits in maize. Through previous studies, QTL that reduce aflatoxin have been identified in several different genetic backgrounds and different generations of breeding including BC_1S_1 and $F_{2:3}$ (Paul et al, 2003), $F_{2:3}$ (Brooks et al, 2005 and Warburton et al, 2009), and recombinant inbred lines (RIL) (Bello, 2007). Only Bello (2007) reported QTL for traits correlated with reducing aflatoxin accumulations (including harder kernel texture and longer husk coverage).

In addition to using multiple environments to better estimate heritability, QTL for different traits need to be estimated across different genetic backgrounds to be of potential broad use (Peccoud et al, 2004). However, from the studies listed above, similar QTL between studies have not been reported and none of these have been followed up by evaluating the populations for QTL in hybrids to evaluate the QTL's usefulness in commercial production fields.

Previous QTL studies of aflatoxin contamination have focused on evaluating inbred lines *per se*. In contrast, evaluating RIL populations as testcrosses might allow for better estimation of QTL for use in a production environment where hybrids are grown. Dominant gene action is primarily observed in cross pollinated crops such as hybrid maize, compared to primarily additive gene action in inbred crops (Falconer and Mackay, 1996). Identification of this dominant gene action might aid in identifying QTL which are more relevant in the production environment.

In this study, we investigated a B73*o2o2* x CML161 recombinant inbred line mapping population in hybrid testcross combinations that had previously been evaluated as lines *per se* (Bello, 2007). The objectives of this study were to: 1) confirm the presence of QTL estimates previously identified in lines *per se*, 2) estimate new QTL for reducing aflatoxin accumulations and agronomic traits and 3) evaluate co-localization of QTL that suggest pleiotropic effects with other measured traits.

MATERIALS AND METHODS

Germplasm

A recombinant inbred line (RIL) population derived from the cross of B73*o2o2* x CML161 composed of 146 $F_{5:6}$ lines was created to estimate QTL for reducing aflatoxin accumulations in maize. B73*o2o2* is a high lysine version of the historic line B73, possessing soft kernels and short loose husks; while, CML161 is a high lysine maize line created by the International Maize and Wheat Improvement Center

(CIMMYT), possessing hard vitreous kernels and long tight husks (Gutierrez et al, 2008). B73*o2o2* is highly susceptible to aflatoxin accumulation as a line *per se* while CML161 has shown reduced levels of aflatoxin accumulation (Bello, 2007). In this study, the B73*o2o2* x CML161 RILs (and parents) were testcrossed to LH195, a commercial line belonging in the stiff stalk heterotic group (Bello, 2007; Gutierrez-Rojas et al 2008; Gutierrez-Rojas et al 2010; Corn States, St. Louis, MO). LH195 is susceptible to aflatoxin accumulations and is used as a stiff stalk tester in the Texas corn improvement program. It has allowed for detection of differences between inbreds when evaluated as hybrids (Betrán et al, 2005; unpublished data). Also included in this trial were several commercially available hybrids as checks (P31B13, Pioneer Hi-Bred; DKC66-80, Monsanto; and BH9012, B-H Genetics). The commercial checks were used to estimate potential aflatoxin reducing capability of a RIL compared to commercial materials.

Field Plot

The testcross hybrids, RIL parents and commercial checks were grown at three locations in Texas: College Station, Corpus Christi, and Weslaco. The College Station and Corpus Christi locations are humid subtropical environments receiving 39” and 30” rain, respectively, on an annual basis (Griffith and Bryan, 1987). Weslaco is described as a semi-arid subtropical environment receiving 23” rain annually (Griffith and Bryan, 1987). The trials were planted at all three environments during 2008 and 2009. Entries were arranged in an α-lattice design, with three replications. All seed was treated prior to planting with Cruiser® insecticide and Maxim® XL fungicide (Syngenta Crop Protection, Greensboro, NC) at label rates.

During 2008, plots consisted of two rows planted 6.4 m and 7.6 m long with 76.2 cm and 101.6 cm between rows at College Station and Weslaco, respectively; while plots at Corpus Christi consisted of one row, planted 5.5 m with 91.4 cm between rows; each location was planted in 3 replicates. Plots during 2009 had the same dimensions and replicates, but due to seed limitations the plot consisted of a single row. To aid in aflatoxin expression at College Station and Weslaco, drought stress was imposed by limiting irrigation prior to and after flowering during grain development, while drought stress at Corpus Christi was imposed by delaying planting five to six weeks (late March to early April) from the optimal maize planting time of the area (late February). Planting later than the optimal time at Corpus Christi allowed crop growth and development after most of the seasonal rainfall has occurred and seasonal temperatures are higher.

Traits Measured

Days to silking and days to anthesis were measured as the number of days from planting until 50% of the plants in a plot have silks exposed and have begun to shed pollen, respectively. Anthesis silking interval (ASI) is measured by subtracting days to anthesis from days to silking, and is an indicator of relative drought stress (Bolanos and Edmeades, 1996). Plant and ear heights were measured from the base of the plant to the top of the tassel and to the node of ear shank attachment, respectively. Ear to plant ratio (EPR) was calculated as: EPR=ear height/plant height. Plant population estimated by counting the number of plants in a plot and converted based on the plot dimensions at each location and is expressed in plants per hectare.

Ten randomly selected ears of each plot were inoculated 10-12 days after silking at College Station and Weslaco with a 3 mL conidial suspension of *A. flavus* isolate NRRL3357 using the non-wounding silk channel method (Zummo and Scott, 1989). Single row plots at Corpus Christi were inoculated by dispersing *A. flavus* colonized corn kernels on the ground between the rows of maize at a rate of 1 kg per 60 m of field row just prior to silking. This approach allows for more natural ear colonization (Betrán *et al*, 2005), using a mixture of locally available isolates. All inoculated ears were hand harvested after the grain dried below 15% moisture; harvested ears were then shelled and bulked. The bulk grain was ground using a Romer™ mill (Romer Labs, Union, MO). Aflatoxin was determined from a 50g subsample of the ground corn, using Vicam Aflatest™ (VICAM, Milford, MA) immunosorbent columns for purification and quantification with the USDA FGIS protocol.

Grain composition (percent oil, protein, and starch) was estimated by analyzing whole inoculated kernels from bulk grain samples with an Infratec 1226 Grain Analyzer, using near infrared transmittance (NIT) (Foss NIR Systems, Inc, Eden Prairie, MN). Due to small sample sizes during 2008, the analysis used three replicates with five subsamples per replicate. Larger samples in 2009 allowed for two replicates with ten subsamples per replicate.

In 2008 at College Station and Weslaco, grain yield and moisture were determined by combine harvesting the plot after the inoculated plots were hand harvested, using a John Deere 3300 combine set up for plot harvest with an HM-1000B Grain Gauge (Harvestmaster, Logan, Utah). Inoculated sample shelled grain weight was added to the grain weight measured on the combine. Single row plots were planted at Corpus Christi, which necessitated hand harvesting the entire plots. During 2009, insufficient seed to plant for combine harvest required all plots to be hand harvested. At College Station and Weslaco, inoculated and non-inoculated plots were shelled and weighed separately. The combined weights of the samples were used to estimate the grain yield for each replication. Grain moisture in 2009 was estimated using a Dole®-Radson Moisture tester (Dole-Radson Moisture Tester, Chatsworth, CA).

Statistical and QTL Analysis

Analysis of variance on individual locations, across environments within a year and across years was conducted using the Proc Mixed procedure from SAS (SAS Inst., Cary, NC). Genotypes, replications, blocks nested within replications and environments were considered random effects in both single location and combined analysis so that best linear unbiased predictors (BLUPs) could be calculated. To equalize the variances and normalize the aflatoxin data, Log_{10} transformation was used (Betrán et al, 2005). Non-transformed and antilogarithmic values are used to report the genotype estimates of Log_{10} transformed data (Betrán et al, 2005). Procedures using SAS software described by Holland et al (2003) and Holland (2006) were used to calculate narrow sense heritability (h^2) and genetic correlations (r^2) (along with respective standard errors) for combined data across years (respectively). In addition to calculating genetic correlations, Pearson Correlation Coefficients were calculated. Subsamples taken on the Infratec Grain Analyzer were evaluated for differences between subsamples using procedures in SAS Proc GLM to test the consistency of the near infrared spectroscopy NIR within and among the samples.

The linkage map reported by Bello (2007) was used to detect QTL in the testcross hybrids using Windows QTL cartographer version 2.5 (Wang et al, 2010). Phenotypic data were subjected to single marker analysis, interval mapping and composite interval mapping to assess for the presence of QTL. One thousand permutations were performed during interval mapping and composite interval mapping to determine the $p < 0.05$ significance threshold for each trait. Markers were selected as cofactors using forward and backward regression. A QTL was declared significant if its calculated likelihood ratio score exceeded that of the selected threshold from the permutations. BLUPs for each trait were used to estimate QTL within year and across year analysis for traits. Composite interval mapping (CIM) explained a larger percentage of the phenotypic variation compared to interval mapping and identified more significant QTL, thus only CIM results are presented here.

RESULTS

Phenotypic Results

As expected, the different environments produced different phenotypic responses for each of the traits measured. Transgressive segregation was observed for all traits; for most traits, the means of the RIL testcrosses trended to the midparent values of the parents (Table 1). The *B73o2o2* testcross flowered later than the CML161 testcross consistently across all environments (Table 1). Grain yield followed a similar trend (except for Weslaco 2009), where the CML161 testcross yields exceeded that of the B73*o2o2* testcross. Grain yield from the CML161 testcross exceeded that of the commercial checks included in the trial by up to 15% at College Station in 2008, but below or equal to the checks during 2009 (data not shown).

Variance Components and Heritabilities

With few exceptions, environmental effects explained the largest percentage of variance components for each of the traits (Table 2).

Table 1. Phenotypic values for B73*o2o2* x CML161 recombinant inbred lines (RILs) testcrosses and parental testcrosses across five Texas environments.

Trait	College Station 2008				Corpus Christi 2008				Weslaco 2008			
	B73*o2o2*	CML161	TC Mean (SE)†	TC Range	B73*o2o2*	CML161	TC Mean (SE)	TC Range	B73*o2o2*	CML161	TC Mean (SE)	TC Range
Aflatoxin ng g^{-1}	125.49	95.40	116.00(129)	92.00-214	113.82	105.75	108(180)	100-156	514.21	457.87	478.00(487)	
Log Aflatoxin	1.94	1.73	1.85(0.44)	1.57-2.04	1.67	1.73	1.73(0.48)	1.36-1.99	2.61	2.40	2.52(0.35)	2.0-3.1
AntiLogAF ng g^{-1}	87.17	53.84	71.46(0)	37.00-110	50.73	53.93	56.28(0)	23.06-97.88	405.35	252.41	335.3(0)	100-1258
Grain Yield t ha^{-1}	3.77	5.84	4.8(0.69)	3.73-6.68	0.31	1.95	1.25(0.28)	0.27-2.7	7.32	7.63	7.55(0.28)	7.27-7.93
Grain Moisture	14.72	14.92	14.75(1.09)	14.17-15.71	.	.	.	.	14.83	15.13	14.99(0.6)	14.54-15.42
Anthesis d	.	.	.	.	.	.	.	.	77.87	77.17	74.96(0.87)	74.06-78.56
Silking d	83.05	82.03	82.5(1.29)	81.06-83.19	65.57	64.08	64.3(1.39)	60.5-67.18	78.90	75.98	76.48(1.02)	74.84-79.57
ASI‡	.	.	.	.	.	.	.	.	1.43	1.43	1.51(0.95)	1.29-1.77
Plant Height cm	224.62	249.63	237.80(5.40)	213-258	.	.	.	.	169.79	197.09	188.00(7)	168-205
Ear Height cm	85.30	100.38	95.44(7.51)	84-107	.	.	.	.	55.47	60.81	59.29(4.73)	52.99-67.75
EPR§	0.380	0.404	0.401(0.031)	0.38-0.42	.	.	.	.	0.316	0.313	0.314(0.026)	0.30-0.34
Lodging %	6.86	9.04	6.65(5.88)	4.023-15.31	.	.	.	.	0.43	0.56	0.46(1.57)	0.43-1.13
Oil g kg^{-1}	3.14	3.26	3.08(0.25)	2.61-3.44	.	3.33	2.9(0.17)	2.12-3.55	3.72	3.91	3.8(0.25)	3.64-4.04
Protein g kg^{-1}	11.49	11.06	11.39(0.25)	10.12-12.4	.	11.34	12.45(0.36)	10.8-13.86	11.13	11.16	11.1(0.69)	10.92-11.24
Starch g kg^{-1}	71.87	71.92	72.00(0.4)	70.98-73.15	.	71.46	71.37(0.4)	70.11-72.61	71.58	70.72	70.85(0.48)	69.76-71.74

Trait	College Station 2009				Weslaco 2009			
	B73*o2o2*	CML161	TC Mean (SE)	TC Range	B73*o2o2*	CML161	TC Mean (SE)	TC Range
Aflatoxin ng g^{-1}	179.72	199.96	187.79(21.31)	87-221	211.19	143.39	223.76(77.92)	135-600
Log Aflatoxin	2.05	2.05	2.05(0.02)	1.99-2.11	2.11	1.91	2.06(0.11)	1.81-2.35
AntiLogAF ng g^{-1}	112.20	112.20	112.20(0)	97-128	128.82	81.28	117.53(0)	64.57-223.87
Grain Yield t ha^{-1}	.	.	.	.	.	65.97	66.32(14.93)	45.24-88.37
Grain Moisture	12.99	12.98	12.98(1.01)	12.96-13.00	14.35	14.52	14.45(0.77)	14.23-14.77
Anthesis	82.32	81.40	81.50(1.37)	80.19-82.79	82.32	81.40	81.5(1.37)	80.19-82.79
Silk	83.28	82.75	82.25(0.54)	80.45-83.83	79.40	77.88	79.02(0.6)	77.63-80.5
ASI	0.69	0.59	0.72(1.23)	0.4-0.97	0.44	0.44	0.45(0.81)	0.44-0.48
Plant Height cm	229.99	244.09	239.08(9.05)	222-259	188.64	188.51	188.42(7.26)	187.65-188.82
Ear Height cm	96.15	98.21	95.26(8.6)	86-109	67.68	67.32	67.64(6.79)	66.9-68.29
EPR	0.41	0.40	0.40(0.03)	0.37-0.45	0.358	0.357	0.358(0.03)	0.356-0.360
Lodging %	42.74	40.45	32.72(17.82)	17.61-55.73	0.62	0.61	0.61(1.96)	0.58-0.62
Oil g kg^{-1}	3.37	3.34	3.43(0.21)	2.85-4.01	3.62	3.92	3.74(0.16)	3.36-4.23
Protein g kg^{-1}	10.64	10.36	10.48(0.52)	9.18-11.95	11.90	10.81	11.6(0.53)	9.6-13.05
Starch g kg^{-1}	71.55	71.65	71.62(0.53)	70.4-72.74	70.99	71.13	70.9(0.45)	69.67-72.64

Not all traits were measured in all environments (.)

†Standard error listed in parenthesis

‡Anthesis silking interval calculated days to anthesis-days to silking

§Ear height to plant height ratio calculated ear height/plant height

Genotypic effects were smaller than environmental effects, but they were significant or highly significant for most traits. Genotype x environmental (G X E) interactions were highly significant for eight of the fifteen traits measured (Table 2). Replicates nested in environment, R(E), were either highly significant or significant; but four traits had no R(E) variation (ear height, EPR, root lodging and protein). Utilizing a Log_{10} transformation of aflatoxin data resulted in a 25% increase in genotype variance component percentage over the untransformed data(Table 2) and also normalized the residuals.

Narrow sense heritabilities (h^2) for aflatoxin and Log_{10} aflatoxin were moderate (h^2 = 0.33 and 0.43). Transformation using the Log_{10} transformation increased h^2 of aflatoxin. The heritabilities of grain composition, with the exception of protein, were moderate to high (Table 2). Heritability for flowering was moderately high (anthesis h^2=0.80 and silking h^2=0.77), while ASI was not significantly different from 0 (Table 2).

Table 2. Percentage of variance components and heritabilities of traits measured across five Texas environments.

Trait	Env	Variance Component[†]					h^2(se[‡])
		G	**E**	**G*E**	**Rep(E)**	**Residual**	
Aflatoxin[§]	**5**	**0.027****	**0.189*****	**0.022**	**0.018*****	**0.745**	**0.33(0.09)**
Log_{10} Aflatoxin	**5**	**0.036*****	**0.264*****	**0.047****	**0.031*****	**0.621**	**0.43(0.08)**
LogGrain Yield	**5**	**0.016*****	**0.835*****	**0.059*****	**0.016*****	**0.075**	**0.51(0.07)**
Grain Moisture	**5**	**0.027*****	**0.41*****	**0.007**	**0.078*****	**0.479**	**0.45(0.09)**
Anthesis	**3**	**0.041*****	**0.813*****	**0.017*****	**0.015*****	**0.114**	**0.80(0.04)**
Silking	**5**	**0.009*****	**0.956*****	**0.005*****	**0.003*****	**0.027**	**0.77(0.03)**
ASI	**3**	**0.002**	**0.221*****	**0.020**	**0.011****	**0.746**	**0.03(0.24)**
Plant Height	**4**	**0.032*****	**0.871*****	**0.021*****	**0.008*****	**0.068**	**0.79(0.03)**
Ear Height	**4**	**0.019****	**0.568*****	**0.011**	**0[§]**	**0.403**	**0.40(0.10)**
EPR	**4**	**0.006**	**0.158*****	**0.010**	**0[§]**	**0.827**	**0.12(0.15)**
Root Lodging	**1**	**0.28*****	**0[§]**	**.**	**0[§]**	**0.736**	**0.07(0.38)**
Stalk Lodging	**2**	**0.003**	**0.701*****	**0.080*****	**0.004****	**0.215**	**0.06(0.23)**
OIL	**5**	**0.106*****	**0.348*****	**0.087*****	**0.023*****	**0.436**	**0.69(0.04)**
Protein	**5**	**0.022***	**0.01***	**0[§]**	**0[§]**	**0.968**	**0.10(0.14)**
Starch	**5**	**0.156*****	**0.248*****	**0.056*****	**0.011*****	**0.528**	**0.78(0.03)**

*Significant at the 0.05 probability level; **Significant at the 0.01 probability level; ***Significant at the 0.001 probability level

[†]Variance component of each effect divided by total variance components: genotype (G), environment (E), genotype x environmental interaction (G*E), replication (Rep(E)). Variance components may not sum to 1 due to rounding error.

[‡]Standard errors are in (). To estimate whether the heritability is significantly (0.05) different from 0, multiply the standard error by 1.96.

[§]Effects consisted of a negative variance component and were rounded to zero

Correlations

Genotypic correlations could not be calculated for traits that lacked significant genetic variation (i.e. grain moisture and anthesis silking interval), with a majority of the variation due to environmental conditions. Due to these omissions in the genetic correlation matrix, phenotypic Pearson Correlation Coefficients were calculated and used to compare between phenotypic and genotypic correlations (Table 3). In general, phenotypic correlations were greater than the calculated genotypic correlations. A few instances occurred where sign change was observed between the two methods of data management (i.e. Aflatoxin and Log Grain Yield) (Table 3).

Phenotypic correlations between aflatoxin or log aflatoxin and the agronomic traits were weak or not detected. In genotypic correlations, stronger correlations between some agronomic traits (silking, starch and protein) and log aflatoxin were detected (Table 3).

Table 3. Phenotypic (below) and genotypic (above) correlations for traits measured across five Texas environments.

						Genotypic Correlations						
	Trait	Aflatoxin	Log Aflatoxin	Log Grain Yield	Grain Moisture	Anthesis	Silking	ASI[†]	Plant Height	Ear Height	Oil	Protein	Starch
Phenotypic Correlations	Aflatoxin	1	0.83(0.22)[‡]	-0.90(4.60)	.[§]	0.23(0.40)	0.66(0.28)	.	-0.40(0.29)	-0.28(0.51)	0.003(0.33)	.	-0.57(0.39)
	Log Aflatoixn	0.70***	1	-0.21(0.29)	.	0.23(0.34)	0.44(0.25)	.	-0.03(0.27)	0.09(0.46)	-0.20(0.29)	0.57(0.03)	-0.36(0.31)
	Log Grain Yield	0.25***	0.35***	1	.	-0.73(18.81)	-0.76(0.12)	.	0.58(0.15)	0.82(0.32)	0.24(0.21)	-0.81(1.81)	0.09(0.21)
	Grain Moisture	0.10***	0.10***	0.27***	1	.	.	.	.	.	.	.	.
	Anthesis	-0.26***	-0.32***	-0.55***	-0.61***	1	1.00(0.04)	.	-0.04(0.24)	-0.81(0.47)	-0.24(0.24)	.	0.10(0.26)
	Silking	0.05*	0.15***	0.70***	-0.31***	0.94***	1	.	0.10(0.02)	-0.20(0.29)	-0.21(0.19)	1.00(1.53)	-0.06(0.19)
	ASI	0.07*	0.15***	0.28***	0.16***	-0.43***	-0.10***	1	-0.06(0.19)	.	.	.	.
	Plant height	-0.28***	-0.31***	-0.28***	-0.3***	0.67***	0.72***	-0.11***	1	0.89(0.28)	0.19(27.26)	-0.98(1.75)	-0.25(0.19)
	Ear height	-0.23***	-0.26***	-0.30***	-0.24***	0.53***	0.59***	-0.13***	0.69***	1	-0.03(0.33)	-0.17(1.07)	0.10(0.33)
	Oil	0.17***	0.22***	0.42***	0.17***	-0.39***	0.11***	0.11***	-0.51***	-0.42***	1	0.34(0.97)	-0.90(0.12)
	Protein	-0.01	0.00	-0.04	0.04	-0.06*	-0.07*	0.19***	-0.07**	-0.03	0.00	1	-0.75(1.40)
	Starch	-0.14***	-0.15***	-0.12***	-0.1***	0.31***	0.14***	-0.14***	0.39***	0.31***	-0.42***	-0.07**	1

*Significant at the 0.05 probability level; **Significant at the 0.01 probability level; ***Significant at the 0.001 probability level.

[†]ASI, anthesis silking interval

[‡]Standard errors in ( ). To estimate whether the heritability is significantly (0.05) different from 0, multiply the standard error by 1.96.

[§]Correlation not calculated due to non significant source of variation.

QTL Analysis

Significant QTL were detected for all traits except protein, with two or more QTL detected for most traits (Figure 1). A total of 96 QTL were detected across all the traits evaluated and these QTL accounted for 6 to 26% of the phenotypic variation observed within each trait. QTL were detected on all chromosomes, ranging from one QTL on chromosome 10 to 11 QTL on chromosome 9 (Fig. 1). QTL for log aflatoxin accumulations were detected on chromosomes 1 and 3, explaining a total of 17% of the phenotypic variation and QTL for aflatoxin were detected on chromosomes 3 and 4, explaining a total of 15% of the phenotypic variation. The QTL for both log aflatoxin and aflatoxin on chromosome 3 were located at the same position; however, the 2-Lod interval for aflatoxin was slightly larger than that observed for log aflatoxin. All QTL for log aflatoxin and aflatoxin reduction were derived from the CML161 parent. Six QTL for silking date were detected on chromosomes 1, 8 and 9. Sixteen QTL for oil content were detected on chromosomes 1, 3, 5, 6, 7 and 9. Eight QTL for starch accumulations were detected on chromosomes 1, 5, 6 and 8. Fifteen QTL for plant height were detected on chromosomes 1, 2, 5, 6, and 8. Four of the plant height QTL are located on chromosome 1 (total of 36% of the variation), with the remainder located on chromosomes 2, 5, 7 and 9 (31% of variation). One QTL for ear height on chromosome 5 explained 7% of the phenotypic variation.

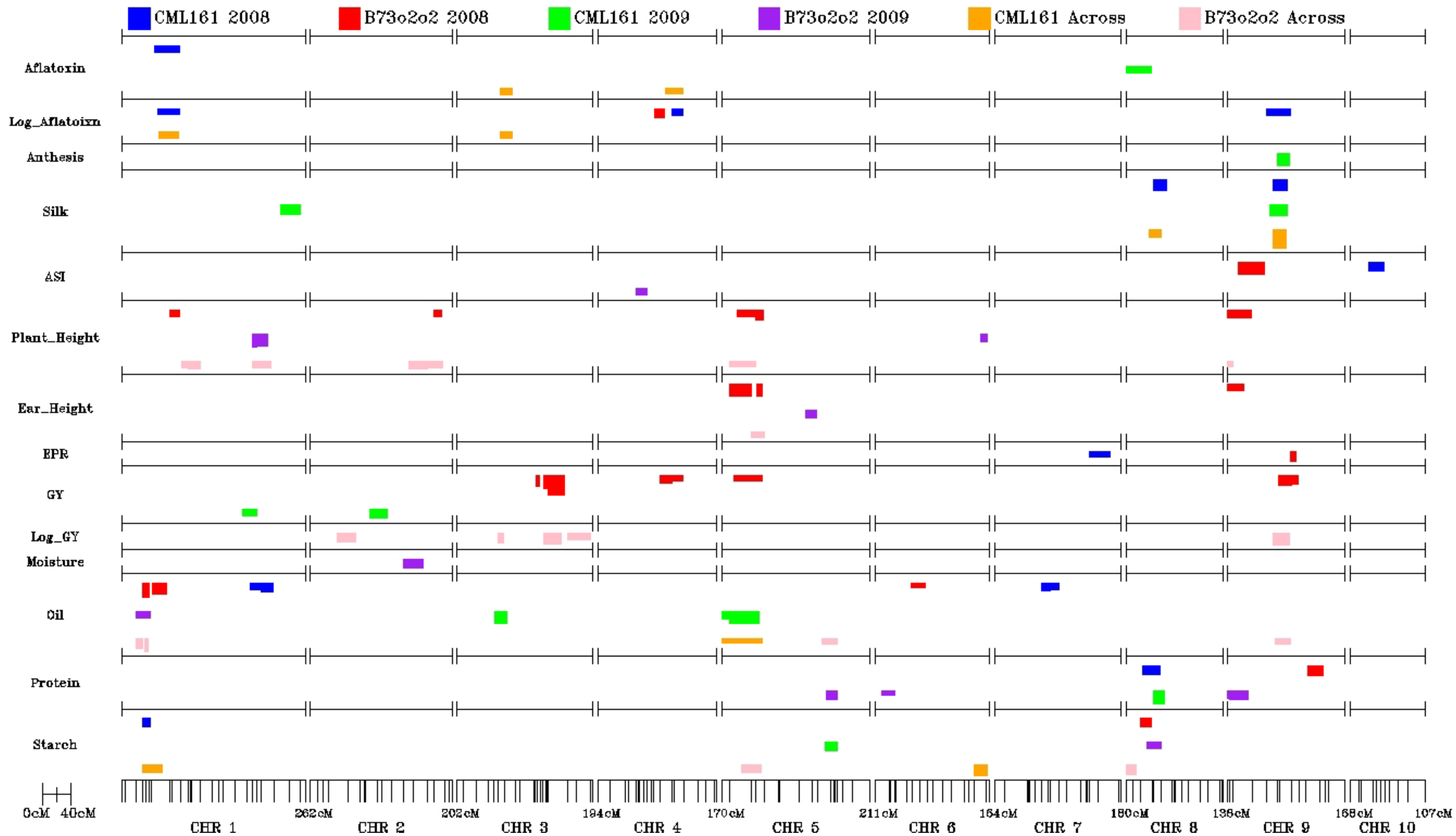

Figure 1. Estimated locations of quantitative trait loci for aflatoxin and other traits measured during 2008, 2009 and across locations estimated from the B73*o2o2* x CML161 recombinant inbred line population testcrossed to LH195. Quantitative trait loci are depicted from the parent. The width of the bar estimates the region the quantitative trait loci covers, while the height of the bar is relative to the r^2 (a measure of the proportion of variation explained) of the QTL ;the taller the bar, the larger the r^2.

DISCUSSION

B73*o2o2* testcrosses accumulated more aflatoxin than the CML161 testcrosses within each environment, except for College Station 2009, which may partly be due to environmental conditions during 2009. Although conditions were conducive for producing aflatoxin (from flowering time until harvest temperatures exceeded 35°C for 71 days and exceeded 37°C for 31 days, with only 45 mm of rain recorded), extreme aflatoxin accumulations were not recorded. The lack of significant variation between testcrosses at College Station during 2009 is a potential issue when calculating BLUPs. The mean of the trial is the same as if LSMeans had been calculated; however, the prediction for all of the entries was reduced around the mean of the test. The observed difference in 2009 using BLUPs is contrary to the expected response of the susceptible parent, B73*o2o2*, accumulating lower aflatoxin than the resistant parent, CML161, but indicative of the variation observed when attempting to quantify aflatoxin accumulations in field trials (Williams *et al*, 2008) and potentially anticipated with the absence of significant ($p>0.05$) differences (Table 2).

In previous studies, the heritability of aflatoxin contamination was been found to be low to moderate (Walker and White, 2001: Campbell and White, 1995 and Warburton et al, 2009). Results reported herein are consistent with those studies. As is typical, most of the variation observed for aflatoxin in this study was due to environmental effects.

The results of the testcross hybrids in this study are similar to those reported in the RILs *per se* (Bello, 2007). Several QTL were detected which were previously detected in *per se* analysis. The major QTL detected for aflatoxin tolerance on chromosome 1 co-located to the same region as QTL detected in *per se* evaluations (Bello, 2007). These consistencies suggest that this region of chromosome 1 is quite important in reducing aflatoxin accumulations in this population both as lines per se and as hybrid testcrosses.

All of the QTL detected for aflatoxin and log aflatoxin came from the CML161 parent (Figure 1). This is contrary to results from *per se* trials with this population (Bello, 2007) where QTL were detected from both CML161 and B73*o2o2*. The QTL for aflatoxin located on chromosomes 4 and 8 were not previously detected in this population. Both aflatoxin and the log transformation detected similar QTL on chromosomes 1, 3 and 4; however, one QTL from each method are detected on chromosomes 8 and 9.

Phenotypic correlation between silking date and log aflatoxin was positive, indicating an increase in aflatoxin as silking date increases. Other studies (Betrán and Isakeit, 2004 and Betrán et al, 2006b) reported negative genotypic correlation with log aflatoxin, which would correspond with a decrease in aflatoxin with an increase in silking date. This increase in aflatoxin as time progressed might suggest environmental conditions may have become more favorable for aflatoxin production as maturity progressed in the random environments that occurred in this study.

Phenotypic correlation between anthesis and silking was relatively high (0.94) (Table 3) as seen in other studies (Ribaut et al, 1996); however, the correlations between silking date and ASI and anthesis date with ASI were low to moderate (0.10 and -0.43, respectively). These correlations are consistent with other maize studies grown under drought conditions. Due to the calculation of ASI, silking date, anthesis date and ASI must be correlated in some manner (Ribaut et al, 1996).

Sign changes between genetic and phenotypic correlations have been attributed to effects based on separate physiological processes controlling the traits (Falconer and Mackay, 1996). In addition to sign changes, co-localization of QTL suggest pleiotrophy or linkage between genes in the QTL. Sign changes were observed between multiple genotypic and phenotypic correlations (Table 3), suggesting multiple processes were involved, controlled by differences in the observed environmental conditions. This could indicate a poor relationship which should not be exploited to improve a trait, e.g. aflatoxin and log grain yield. Genetic correlation sign changes have also been implicated in two locus linkage and whether the two loci are in coupling phase or repulsion phase linkage (Bernardo, 2002). Thus the use of the sign change and the estimated QTL locations determines whether a trait is in linkage with another trait or the traits are pleiotropic. Alternatively, QTL for oil, protein and starch located at the same loci (different 2-Lod intervals) on chromosome 5 are almost certainly due to pleiotropic effects since they are all reported as percentage of the seed. As one trait increases, the others must drop and this explains the moderately high genetic correlation between starch, oil and protein.

Examples of QTL which colocalize include oil and silking date on chromosome 9 and are estimated within a similar 2-Lod interval QTL for oil and starch located in similar regions on chromosomes 1 and 5. QTL for aflatoxin, silking and grain yield co-localize on chromosome 9. Chromosome 6 contains QTL which co-localize for plant height, ear height, grain yield and oil content. Co-localization of QTL for agronomic traits and aflatoxin or log aflatoxin was observed; especially on chromosomes 1, 3, 4, 8 and 9. QTL co-localization with aflatoxin was observed among, days to silking, protein content and starch content on chromosome 8 (Figure 1).These co-localizations are consistent with the genotypic correlations observed (Table 2). An additional co-localization on chromosome 9 was with Log_{10} aflatoxin and silking across years. The silking QTL located on chromosome 9 is likely the same QTL detected in other studies (Chardon et al, 2004 and Buckler et al, 2009). An association between silking date and aflatoxin accumulation has been reported previously (Betrán et al, 2002; Betrán et al, 2004, Betrán et al, 2006b), and appears to be a combination of traits which need to be further studied to identify genes which reduce aflatoxin in maize. No significant correlation or co-localization between aflatoxin and oil were detected despite reports of *Aspergillus* initially colonizing and producing more aflatoxin in the embryo of the maize seed (Smart et al, 1990 and Brown et al, 1995).

One potential gene related to reducing aflatoxin has been identified and found to be expressed in the silks. Widstrom et al (2003) reported maysin to have antimicrobial properties as well as insecticidal properties with efficacy against lepidopteron species. A QTL in bin 1.03 at the *p1* locus for silk antibiotic compounds (Widstrom et al, 2003) was identified. QTL were detected in the B73o2o2 x CML161 population for reducing aflatoxin located at marker UMC2096 (Figure 1), which is at the same location as the gene *p2.* The *p2* has been reported the same as *p1*, including affecting maysin production (Zhang et al, 2003).

Considering the number of flowering QTL reported by Buckler *et al* (2009) and Chardon *et al* (2004), the number of QTL detected for in this study is small. Furthermore, the largest effect QTL for flowering detected in this population was considerably less than the largest effect QTL detected by Buckler et al (2009) (0.262 vs. 1.7 days). The differences are likely due to the range in maturity in the different studies; parents in this study were much closer in maturity compared to the previous reports.

Many factors can aid in positive detection of both real and false positive QTL (Bernardo, 2004). This population is sufficient in size for mapping QTL and a similar number of QTL were identified in *per se* evaluation; though not all the same QTL. Mapping QTL in an inbred population will primarily identify loci with additive effects, while mapping QTL in a hybrid testcross will identify both additive and dominant effects relative to the testcross parent. Kerns et al (1999) used hybrid testcrosses to confirm QTL which were detected in $S_{4:6}$ maize lines for agronomic improvement in Lancaster-type germplasm; while, Jines et al (2007) used RIL top crosses to map rust resistance in maize. These dominant effect QTL are particularly important in crops where hybrids are commercialized.

Even though this population is of sufficient size to detect QTL, the trial was repeated in five unique environments with three replications each to get more accurate estimates of true effects. Genotype x environment interaction was significant for flowering time, and both silking and anthesis. Significant genotype x environment interaction creates additional variance that can hinder identification of more QTL in given traits. Loci detected for silking and anthesis appeared to be consistent across environments (e.g. chromosome 9) and contributed by the same parent. Chardon *et al* (2004) identified a region of chromosome 9 syntenic with identified genes in the rice genome. This region is linked to the same marker as the QTL for flowering identified in this study. Given what we know about the importance of time to flowering among many traits, this suggests that each of the traits (aflatoxin, grain yield and oil) which co-localize to this QTL region may be a function of flowering time. For example, the importance of flowering time in aflatoxin is that weather on one day may be more beneficial for fungal growth or toxin production than another day.

As evidenced by high environment and genotype x environmental interaction variance components, this variation is important when estimating QTL for aflatoxin accumulation. Using the same population derived from the B73*o2o2* x CML161 cross as lines *per se*, Bello (2007) in two environments identified QTL affecting aflatoxin from both parents; however, the QTL detected by Bello (2007) came mainly from

CML161. In three other aflatoxin QTL studies Brooks et al (2005) evaluated their germplasm in five environments, Paul et al (2003) used two environments, and Warburton et al (2009) used four environments. All four studies reported few QTL significant in more than one environment; the most was Warburton et al (2009) who identified one QTL in all four environments and one QTL in two environments. In this study three QTL one on each of chromosomes 1, 4 and 9 were detected across multiple years.

CONCLUSION

Further evaluation of QTL may lead to identification of genes involved with the alleles affecting aflatoxin accumulation in maize. Within the traits measured, flowering time appears to be most related to aflatoxin accumulations in this population. Identification and mapping traits related to aflatoxin accumulations in maize could aid in reducing preharvest aflatoxin accumulation when these loci are incorporated via marker assisted selection.

EVALUATION OF A SUBSET OF MAIZE RECOMBINANT INBRED LINE TESCROSSES FOR AGRONOMIC DESIRABILITY

INTRODUCTION

Aflatoxins, produced by *Aspergillus flavus* FR: Link are classified as Group I carcinogens (IARC, 2010), causing liver cancer and hepatocemic cancer (Castegnargo and McGregor, 1996). No commercial maize germplasm is currently resistant to preharvest aflatoxin accumulations, although quantitative variation exists (Abbas et al, 2002). Identification of germplasm resistant to aflatoxin accumulations could greatly benefit maize producers in the southern United States and areas prone to chronic preharvest aflatoxin accumulations.

Several sources of resistant germplasm have been released but these sources lack the agronomic potential to be used directly in a commercial breeding program (Llorente et al, 2004; Williams and Windham, 2001; Scott and Zummo, 1990). Several tropical sources of maize germplasm have been identified to reduce aflatoxin accumulations (Betrán et al, 2005; Williams and Windham, 2006; Menkir et al, 2008). Some of these tropical sources have the ability to produce grain yields similar to temperate hybrids, but lack the adaptation to grow competitively in the southern United States (Betrán et al, 2005).

Several recombinant inbred line (RIL) populations have been used to detect quantitative trait loci (QTL) for reducing aflatoxin accumulations in maize (Bello, 2007; Warburton et al, 2009) and identifying QTL affecting grain yield (Austin and

Lee, 1996). A secondary goal of creating a recombinant inbred line population is the identification of germplasm superior to the parents used to make the population, through transgressive segregation, beyond detecting QTL for the desired traits. A literature search, however, revealed no RIL maize populations evaluated in hybrid testcrosses for evaluating aflatoxin reducing properties. The use of testcrosses in maize might better estimate QTL which are important to maize producers. Testcrosses will also allow for better estimation of agronomic qualities and potential identification of RILs which might have agronomic desirability along with QTL associated with reducing aflatoxin accumulations.

Multiple environment testing is important to better estimate a genotype's potential across a large growing area. The use of multiple environments for testing has allowed for selection of many improved genotypes. The objective of this research was to evaluate grain yield and other agronomic traits of selections from a RIL population in testcrosses at multiple locations across Texas.

MATERIALS AND METHODS

Germplasm

Entries for this trial were selected progeny from a recombinant inbred line (RIL) population derived from a cross of B73*o2o2* and CML161. B73*o2o2* is the high lysine version of the historic stiff stalk inbred line B73. B73*o2o2* exhibits a soft kernel texture and short loose husk coverage of the ears. CML161 is a high yielding, high lysine tropical line from the International Maize and Wheat Improvement Center

(CIMMYT). CML161 exhibits hard kernels and long tight husk coverage of the ears. The recombinant inbred line population was created to map potential quantitative trait loci for reducing preharvest aflatoxin accumulations and related traits (e.g.: kernel texture and husk coverage) (Bello, 2007). Recombinant inbred lines and parents (*B73o2o2* and CML161) were test crossed to a temperate tester (LH195, Corn States, St. Louis, MO) due to its ability to produce high yielding hybrids and previous use in this program (Betrán et al, 2005). LH195 belongs in the stiff stalk heterotic group (Mikel and Dudley, 2006).

For 2008, the top and bottom fifteen lines, based on aflatoxin accumulation in inbred *per se* (Bello, 2007) were selected for further testing. Entries for 2009 were selected based on testcross yield performance measured in the aflatoxin accumulation trials, selecting the 30 top yielding hybrids from across three induced water stress locations (Mayfield et al, 2009).

Field Plots

Agronomic trials were planted at four locations (College Station, Weslaco, Hondo and Wharton) in Texas during 2008 and 2009 on dates typical for corn production in the region (Table 4). The trials at College Station and Weslaco were grown at Texas AgriLife Research facilities, while the trials at Hondo and Wharton were grown in producers' fields. Each location in both years was grown for optimal yields using standard agronomic practices for the region. The plots at College Station, Weslaco and Hondo were grown as irrigated locations; while, plots at Granger and Wharton were grown under rain fed conditions (Table 4).

Entries were planted in two row plots with two replicates. Plots at College Station were planted 6.4 m long, while Weslaco, Hondo, Wharton and Granger were planted 7.62 m long (plot length at trial locations with concurrent research). All seed was treated prior to planting with Cruiser® insecticide and Maxim® XL fungicide (Syngenta Crop Protection, Greensboro, NC) at label rates, in order for the test crosses to be treated the same as the commercial hybrids included in the trial

Table 4. Planting dates, agronomic and plot descriptions of select recombinant inbred line testcrosses grown at four and three locations during 2008 and 2009.

	Date Planted	Irrigation #/cm†	Rain Fall‡	Soil Type	Plot Length	Row Spacing
			2008			
College Station	02/29/2008	3/23cm	33cm	Ships Clay Loam	6.4 m	76 cm
Weslaco	02/24/2008	6/76cm	20cm	Raymondville clay Loam	7.62 m	102 cm
Wharton	03/20/2008	NI	58cm	Lake Charles Clay Loam	7.62 m	102 cm
Hondo	03/13/2008	10/38cm	NR	Victoria Clay	7.62 m	96 cm
			2009			
College Station	02/27/2009	4/30cm	15cm	Ships Clay Loam	6.4 m	76 cm
Weslaco	02/18/2009	4/61cm	9cm	Raymondville clay Loam	7.62 m	102 cm
Hondo	03/10/2009	5/45cm	17cm	Montell Clay	7.62 m	96 cm

†Number of irrigations applied during the season. NI=Not irrigated.
‡Rain fall received during the growing season. NR= not recorded

Traits measured at each of the locations included grain yield, grain moisture, test weight, days to silking, plant height, ear height, ear height to plant height ratio (EPR), plant population and stalk lodging. Grain yield, grain moisture and test weight were measured by harvesting the plots with a John Deere 3300 combine with a Harvest Master HM-1 Grain Gauge (Harvest Master, Logan, UT). Days to silking were calculated as the number of days from planting until 50% of the plants with in a plot had silks showing. Plant and ear height were measured from the ground to the tip of the tassel and the node where the ear shank attaches, respectively. EPR was calculated as EPR=ear height divided by plant height (Betrán et al, 2005). Stalk lodging is reported as a percentage of plant population with plants broken below the ear.

Statistical Analysis

Data analysis for this paper was generated using SAS Proc Mixed procedures, using Version 9.2 (SAS Institute, Cary, NC). Genotypes were considered fixed, in order to generate best linear unbiased estimators (BLUEs). Replications, locations and genotype x environment interaction were all considered random factors. Due to the highly unbalanced data between years, years were analyzed separately.

RESULTS

Due to the method of selection, only seven entries were common between the two years. Significant differences were observed for most traits at most locations and across locations within each year (Tables 5 & 6). Genotype x environment interaction

Table 5. Analysis of variance and heritabilities for traits measured in selected recombinant inbred line testcrosses grown at four Texas locations during 2008.

Source	df	Grain Yield	Grain Moisture	Test Weight	Silk	Plant Height	Ear Height	EPR	Plant Population	df[†]	Stalk Lodging
Entry	34	9.93***	7.20***	10.91***	2.13	641.54***	302.18***	0.002***	$1.5x10^{8}$***	34	1.08
Loc	3	86.56**	150.60***	194.77***	3784.54***	25585***	16938***	0.116**	$3.9x10^{9}$***	1	0.6
Loc*entry	102	0.63**	0.90***	1.94***	1.75*	92.42	53.59*	0.0009	$3.1x10^{7}$*	34	0.89
Rep(Loc)	4	2.52***	1.32***	1.63	0.85	40.39	147.67**	0.003**	$5.1x10^{7}$	2	0.89
Error	136	0.39	0.26	1.04	1.2	75.12	38.37	0.0008	$2.2x10^{7}$	68	0.76

*Significant at 0.05; ** Significant at 0.01; *** Significant at 0.001 levels

[†]Lodging was only measured at College Station and Weslaco

‡Standard errors in ().

Table 6. Analysis of variance and heritabilities for traits measured in selected recombinant inbred line testcrosses grown at three Texas locations during 2009.

Source	Df	Grain Yield	Grain Moisture	Test Weight	Silk	Plant Height	Ear Height	EPR	Plant Population	df[†]	Stalk Lodging
Entry	34	2.07*	1.03*	5.78*	7.67***	529.80***	225.94*	0.003	$8.6x10^{7}$***	34	1.08
Loc	2	1.8	58.24**	1071.86**	556.42***	65550**	21768	0.06*	$5.8x10^{9}$***	1	0.6
Loc*entry	68	1.31	0.63**	3.53***	2.37*	89.16*	120.22	0.002	$2.3x10^{7}$**	34	0.89
Rep(Loc)	3	6.33***	1.36*	15.29***	4.05	709.78***	44.67	0.001	$1.0x10^{7}$	2	0.89
Residual	102	0.81	0.34	1.26	1.62	56.48	144.05	0.002	$1.3x10^{7}$	68	0.76

*Significant at 0.05; ** Significant at 0.01; *** Significant at 0.001 levels

[†]Lodging was only measured at College Station and Weslaco

‡Standard errors in ().

was significant for most traits within both 2008 and 2009. Heritabilities were generally lower during 2009 compared to 2008 (Tables 5 & 6).

During 2008, significant differences for grain yield across environments were observed. None of the RIL test crosses produced as much grain as the commercial checks (Table 7). The highest yielding RIL testcross (RIL-3; 7.25 t ha^{-1}) produced 10% less grain yield than the lowest yielding commercial check (BH8913; 8.08 t ha^{-1}) (Table 7).

Mean grain yield for 2009 was essentially the same as 2008 (6.30 t ha^{-1} vs. 6.31 t ha^{-1}, respectively) (Tables 7 and 8); however, less variation around the mean was observed in 2009 (4.76 – 7.80 t ha^{-1}) compared to the variation around the mean in 2008 (3.06 – 9.10 t ha^{-1}) (Tables 7 and 8). The reduction in variance around the mean is likely due to the fact that entries selected for testing during 2009 were selected on the basis of grain yield from testcrosses grown during 2008, compared to selecting entries for 2008 from inbred per se aflatoxin data. Significant differences for genotype ($p<0.05$) were detected for grain yield during 2009, however, no significant GxE interactions were detected. Five of the RIL testcrosses (RIL 244, RIL 190, RIL 145, RIL 91, and RIL 59) yielded within 17% of the highest yielding commercial check (7.80 t ha^{-1}) during 2009 (Table 8).

Table 7. Means for traits measured in selected recombinant inbred line testcrosses grown at four Texas locations during 2008.

Test cross	Grain † Yield	Grain Moist	Test Weight	Silk	Plant Height	Ear Height	EPR ‡	Plant Pop	Stalk Lodging	Aflatox in§
	tn ha^{-1}	g kg^{-1}	kg hl^{-1}	days	cm	cm		Plants ha^{-1}	%	ng g^{-1}
RIL-3	7.25	14.09	76.61	75.1	212.09	86.05	0.40	61904	0.30	115.44
RIL-9	6.45	12.11	75.01	74.0	219.40	85.71	0.39	51531	0.00	104.83
RIL-28	6.85	12.68	77.03	74.0	221.60	92.39	0.41	60961	0.35	119.39
RIL-37	6.85	13.90	77.00	74.6	213.36	83.84	0.39	59609	0.70	103.08
RIL-45	6.48	11.98	75.06	74.3	219.71	87.31	0.40	55452	1.23	106.15
RIL-82	6.38	12.76	76.81	74.5	232.71	94.94	0.41	59798	0.00	105.56
RIL-97	5.88	12.60	77.65	74.5	202.89	78.11	0.38	56632	0.00	107.95
RIL-99	5.41	13.43	77.63	74.4	212.41	81.61	0.38	50547	0.00	126.92
RIL-101	5.83	12.91	76.36	73.9	223.52	90.49	0.40	62247	0.00	98.57
RIL-109	4.70	11.60	74.81	74.9	205.10	87.34	0.42	55142	0.38	99.16
RIL-111	5.63	13.43	76.40	74.7	224.16	85.74	0.38	58037	0.00	107.76
RIL-118	6.26	12.33	76.05	74.7	220.02	82.55	0.37	60768	2.25	101.93
RIL-138	6.51	13.34	77.81	74.8	220.34	96.84	0.43	61457	1.68	113.62
RIL-144	6.31	15.31	76.91	73.7	234.64	99.70	0.42	58315	0.00	112.31
RIL-162	5.91	15.66	78.86	74.7	212.41	82.24	0.39	58842	0.00	118.98
RIL-165	6.93	13.43	76.39	73.9	233.37	91.44	0.39	59747	0.00	100.66
RIL-180	6.53	13.54	78.95	74.6	209.85	84.14	0.40	61012	0.00	100.97
RIL-186	5.45	13.38	76.03	74.8	214.31	85.74	0.40	56044	0.00	107.71
RIL-195	7.11	13.11	76.59	74.0	213.99	88.28	0.41	58216	0.00	121.41
RIL-207	5.00	12.15	76.50	74.8	203.51	75.56	0.37	53723	0.00	99.37
RIL-217	4.43	12.48	77.74	75.3	213.99	76.53	0.36	57520	0.00	129.02
RIL-233	6.70	13.76	76.99	74.4	215.90	87.64	0.40	57763	0.65	121.57
RIL-237	6.13	12.89	77.66	74.1	218.75	85.09	0.39	60215	0.00	106.65
RIL-251	5.96	12.79	78.39	75.1	221.95	89.53	0.40	55495	0.00	114.16
RIL-256	6.21	13.35	77.13	74.4	209.55	79.36	0.38	59223	0.83	110.58
RIL-260	6.00	13.68	77.93	74.8	229.86	92.39	0.40	58621	0.00	117.55
RIL-269	6.74	13.45	77.21	74.9	230.19	96.20	0.41	57689	0.00	114.30
RIL-274	6.05	13.19	76.53	75.3	226.37	94.30	0.41	51693	0.43	105.69
RIL-276	6.25	12.03	75.44	74.4	214.64	83.81	0.39	62463	0.35	103.44
RIL-282	6.86	14.01	78.35	74.3	224.15	87.60	0.39	61432	0.35	109.26
RIL-285	6.81	14.24	76.70	73.9	228.29	84.78	0.37	59781	0.00	102.55

Table 7. (continued).

Test cross	Grain † Yield	Grain Moist	Test Weight	Silk	Plant Height	Ear Height	EPR ‡	Plant Pop	Stalk Lodging	Aflatoxin§
	tn ha^{-1}	g kg^{-1}	kg hl^{-1}	days	cm	cm		Plants ha^{-1}	%	ng g^{-1}
B73o2	3.06	11.15	73.49	75.0	202.56	75.88	0.37	41709	0.58	115.58
P31B13	9.10	12.83	76.75	73.0	227.95	96.53	0.42	62473	0.00	117.3
DKC69-70	8.85	13.35	77.39	73.8	230.17	91.45	0.39	65554	0.00	.
BH8913	8.08	11.84	75.55	73.6	220.66	87.63	0.39	56462	0.00	.
Mean	6.31	13.11	76.79	74.4	218.98	87.11	0.40	57945	0.29	108.27
LSD	0.72	0.58	1.17	1.4	9.93	7.09	0.03	5326.25	1.77	.
CV	9.89	3.89	1.33	1.3	3.96	7.11	7.15	8.03	303.60	.

†All Recombinant inbred lines are testcrossed to LH195. B73o2o2 was testcrossed to LH195. P31B13, DKC69-70 and BH8913 are included as commercial hybrid checks.

‡ Ear to Plant Ratio is calculated: Ear height/Plant height

§ AntiLog of Log of transformed Aflatoxin BLUPs from aflatoxin test, grown under drought stress conditions during 2008

Table 8. Means for traits measured in selected recombinant inbred line testcrosses grown at four Texas locations during 2009.

Test cross	Grain Yield	Grain Moist	Test Weight	Silk	Plant Height	Ear Height	EPR‡	Plant Pop	Stalk Lodging	Aflatoxin
	tn ha^{-1}	g kg^{-1}	kg hl^{-1}	Days	Cm	cm		Plants ha^{-1}	%	ng g^{-1}
RIL-3	6.16	12.95	75.80	79.3	214.00	80.33	0.37	59156	30.13	102.33
RIL-262	5.88	13.38	78.03	78.8	214.67	76.33	0.35	56020	9.27	.
RIL-59	6.57	13.27	77.41	78.8	231.00	86.50	0.37	60741	11.79	107.15
RIL-82	6.29	13.05	76.22	78.0	233.67	85.83	0.37	59306	17.82	120.33
RIL-91	6.54	13.48	76.79	79.0	233.67	90.33	0.38	59519	5.79	117.49
RIL-92	5.86	13.22	77.39	78.2	215.00	83.50	0.39	63926	25.19	112.20
RIL-106	6.38	13.53	78.89	75.7	221.00	86.50	0.39	62960	4.51	81.28
RIL-137	6.12	14.08	77.12	79.2	245.00	79.00	0.32	63589	27.86	117.49
RIL-144	5.89	13.78	77.76	79.0	241.00	95.67	0.39	63061	34.26	79.43
RIL-145	6.68	13.55	77.72	78.2	236.17	96.17	0.40	62495	14.75	112.20
RIL-147	6.34	13.72	76.95	78.8	229.50	78.67	0.34	57738	11.63	109.65
RIL-150	6.17	13.17	76.04	76.0	203.50	69.83	0.34	54620	22.72	.
RIL-165	6.08	13.55	77.13	78.5	224.50	84.83	0.38	53501	17.05	147.91
RIL-174	6.30	13.37	76.23	79.0	232.17	83.67	0.36	59435	12.86	87.10
RIL-180	6.32	13.40	78.01	78.0	213.84	80.17	0.37	57923	11.54	104.71
RIL-190	7.12	13.73	77.17	76.8	222.34	86.83	0.39	57761	15.33	117.49
RIL-195	5.99	13.28	76.64	77.7	216.00	86.33	0.40	58740	7.35	134.90
RIL-199	5.74	13.82	76.72	79.8	222.84	85.67	0.38	60103	21.80	83.18
RIL-205	4.76	12.53	75.36	78.2	218.50	79.00	0.36	55606	33.79	77.62
RIL-213	6.16	12.95	76.08	78.3	215.84	87.17	0.40	60670	3.59	.
RIL-216	6.35	13.38	77.23	77.0	215.00	80.33	0.37	53889	11.50	100.0
RIL-220	6.15	14.05	77.32	78.3	215.00	83.33	0.39	58788	9.25	120.23
RIL-222	6.33	13.25	75.54	78.5	222.34	91.50	0.41	53806	15.17	151.36
RIL-229	6.20	13.32	77.01	80.0	232.50	87.67	0.37	63930	29.34	77.62
RIL-232	5.72	12.85	74.84	78.7	228.67	82.00	0.36	52477	21.08	114.82
RIL-233	6.33	13.77	76.79	78.8	216.34	87.83	0.40	61934	27.74	95.50
RIL-239	5.97	13.25	77.15	75.7	224.34	81.33	0.36	52012	14.83	83.18
RIL-241	5.77	13.28	77.49	78.5	222.17	87.00	0.39	61889	15.68	109.65
RIL-244	7.23	12.62	75.05	77.8	225.84	87.83	0.39	60372	5.24	114.82
RIL-260	5.41	14.00	78.41	78.5	227.00	71.83	0.32	64029	31.09	158.49
RIL-272	6.48	13.48	75.89	79.3	226.34	95.00	0.42	53074	9.78	85.11

Table 8. (continued).

Test cross	Grain Yield	Grain Moist	Test Weight	Silk	Plant Height	Ear Height	EPR ‡	Plant Pop	Stalk Lodging	Aflatoxin
	tn ha^{-1}	g kg^{-1}	kg hl^{-1}	days	cm	cm		Plants ha^{-1}	%	ng g^{-1}
CML161	6.60	13.95	78.22	78.0	237.50	94.83	0.40	65074	31.45	93.33
P31B13	7.80	13.70	77.45	76.7	232.17	90.33	0.39	62626	9.11	117.49
DKC69-70	7.13	12.80	76.20	77.0	238.17	87.83	0.37	61790	15.93	.
BH8913	7.66	14.27	78.36	76.0	233.17	88.00	0.37	62717	2.20	.
Mean	6.30	13.42	76.93	78.2	225.17	85.11	0.38	59294	16.81	115.70
CV	14.29	4.34	1.46	1.6	3.34	14.10	11.90	6.08	5.19	24.00
LSD	1.27	0.82	1.58	2.3	10.58	16.89	0.06	5073.4	1.73	.

†All Recombinant inbred lines are testcrossed to LH195. CML161 was testcrossed to LH195. P31B13, DKC69-70 and BH8913 are included as commercial hybrid checks.

‡ Ear to Plant Ratio is calculated: Ear height/Plant height

§ AntiLog of Log of transformed Aflatoxin BLUPs from aflatoxin test, grown under drought stress conditions during 2008

Mean test weight observed in both years was similar (2008: 76.79 kg hl^{-1} compared to 2009: 76.93 kg hl^{-1}). Variance around the mean was lower in 2009 (Table 6) than in 2008 (Table 5). Six of the testcrosses produced significantly higher test weights than the commercial checks in 2008 (Table 2). During 2008 RIL-180 produced the highest test weight (78.95 kg hl^{-1}); however, during 2009 although it was not the highest, but was not different from the highest (RIL-106, 78.00 kg hl^{-1}) or two commercial hybrids (P31B13 and BH8913).

The commercial hybrids included during 2008 tended to silk earlier than the RIL testcrosses. The highest yielding testcross, RIL-3 (75.13 d), silked almost two days after the latest commercial hybrid, DKC6-70 (73.75 d) (Table 6). The range in silking was greater in 2009 than in 2008 (4.33 d vs. 2.25 d, respectively) (Tables 7 and 8). Two of the highest yielding testcrosses, RIL-190 and RIL-244 (76.83 d and 77.83 d, respectively), were among the earliest flowering of the testcrosses during 2009.

DISCUSSION

One goal of creating recombinant inbred lines is the identification of germplasm superior to either parent for traits beyond the trait of interest in development of the RIL population. B73*o2o2* has been identified as an inferior parent compared to its normal B73 type grain. Crossing B73*o2o2* with LH195 did not yield a good comparison as both inbreds are in the same heterotic pattern which could be seen in 2008 (Table 7). In contrast, CML161 crossed with

LH195 produced a hybrid capable of producing grain yield similar to the commercial checks (Table 8) during the 2009 trial, (Both B73*o2o2* and CML161 testcrosses were not included in both years due to lack of planting seed.) Lower yielding entries observed in this trial may follow similar heterotic pattern to B73*o2o2* which could not be observed given the tester used. The ideal situation would have been to testcross the entire population to a tester from both the stiff stalk group and the Lancaster group.

Reduced variance around the mean observed between 2008 and 2009 was likely a function of the method of selection of the entries included in the trial (Tables 7 and 8). Testcrosses for 2008 were selected based on aflatoxin data in *per se* trials under inoculation (Bello, 2007). This selection may have presented a randomness not followed in selecting entries for 2009. Entries for 2009 were selected based on grain yield observed in aflatoxin trials conducted in 2008 (Mayfield, 2009), which were subjected to drought stress in an attempt to increase preharvest aflatoxin accumulations. Edmeades et al (1999) showed selecting under drought stress in maize to be an effective method of improving grain yield. Specifically, RIL-145, RIL-190 and RIL-244 were selected based on performance under drought conditions. Importantly, yields for these three testcrosses were similar to that of the commercial checks (Table 8) in well watered environments during 2009 confirming that selection under drought conditions was useful for identifying superior lines.

Of the RILs tested, seven testcrosses were tested in both years. RIL-3 was the highest yielding testcross during 2008 but it was not as good in 2009. This may be due to selection of entries for 2009. In both years, RIL-3 produced approximately 15% less grain than the lowest yield of the commercial checks. The potential loss of heterosis is one possible explanation as to why the RIL testcrosses yield less than the commercial hybrid checks in both years of this study. Each of the RILs is theoretically expected to be 50% stiff stalk and 50% exotic across the genome. Using a single heterotic group tester (stiff stalk), we would expect vigor observed from heterosis to be about 50% less than when using a pure heterotic group cross.

The recombinant inbred lines evaluated as testcrosses in this trial were also evaluated for aflatoxin accumulation during both 2008 and 2009 in a separate trial across both years. The testcrosses evaluated during 2008 and 2009 for agronomic performance in these trials accumulated fewer aflatoxins in the aflatoxin trial than the commercial checks included in the aflatoxin trial (Tables 7 and 8). However, the testcrosses which accumulated the fewest aflatoxins in both 2008 and 2009 trials were usually not testcrosses which produced high grain yields (Tables 7 and 8). This might suggest that yield and aflatoxin resistance are negatively correlated, either due to pleiotropy, or linkage. Among the lines investigated, RIL-195 is the closest testcross to producing high grain yield and reduced aflatoxin compared to the commercial checks. During the 2009 aflatoxin trial, RIL-195 accumulated 135 ng g^{-1} aflatoxin under drought stress, while producing 5.1 Mg ha^{-1} of grain; compared to a commercial check included in the aflatoxin trial which accumulated 304 ng g^{-1} and produced 4.9 tn ha^{-1} (Mayfield, 2009). In addition to reduced aflatoxin and high grain yield, grain moisture was lower in several testcrosses compared to the checks during 2008, despite flowering at a later date (Table 7). This might suggest a faster grain filling period or a faster dry down. A faster dry down might help in reducing aflatoxin accumulations. Aflatoxin production generally occurs between 18 – 30% grain moisture; however, if the rate of grain dry down is increased, then it may be possible to have reduced aflatoxins in the field.

Recombinant inbred lines have been utilized to map quantitative trait loci for many traits in multiple crops (You et al, 2006; Warburton et al, 2009). This study is an example that recombinant inbred lines can be used, in addition to mapping traits, for selecting improved germplasm through transgressive segregation for traits other than those originally identified in the parents used to create the RILs. Traits measured in this study grain yield, grain moisture, test weight, days to silking, plant and ear height, ear height to plant height ratio and stalk lodging were measured. Although none of the RILs produced testcrosses which exceeded the yield of the commercial hybrids, several of the RILs identified in this study need to be further characterized for potential sources of germplasm with improved agronomic potential coupled with reduced aflatoxin accumulations compared to the commercial checks (Table 9). In addition to this population, other previously researched RIL populations which used an improved parent need to be evaluated for usefulness as a germplasm source outside of mapping.

Table 9. Selected RILs from 2008 and 2009 to follow up with further testcrosses.

2008

Testcross	Grain Yield	Grain Moisture	Test Weight	Silk	Plant Height	Ear Height	EPR	Stalk Lodging	Aflatoxin
	tn ha^{-1}	g kg^{-1}	kg hl^{-1}	Days	cm	cm		%	ng g^{-1}
RIL-101	5.83	12.91	76.36	73.9	223.52	90.49	0.4	0	98.57
RIL-109	4.7	11.6	74.81	74.9	205.1	87.34	0.42	0.38	99.16
RIL-207	5.0	12.15	76.5	74.8	203.51	75.56	0.37	0	99.37
RIL-165	6.93	13.43	76.39	73.9	233.37	91.44	0.39	0	100.66
Mean	6.31	13.11	76.79	74.4	218.98	87.11	0.4	0.29	108.27

2009

Testcross	Grain Yield	Grain Moisture	Test Weight	Silk	Plant Height	Ear Height	EPR	Stalk Lodging	Aflatoxin
	tn ha^{-1}	g kg^{-1}	kg hl^{-1}	Days	cm	cm		%	ng g^{-1}
RIL-205	4.76	12.53	75.36	78.2	218.5	79	0.36	33.79	77.62
RIL-229	6.2	13.32	77.01	80.0	232.5	87.67	0.37	29.34	77.62
RIL-144	5.89	13.78	77.76	79.0	241	95.67	0.39	34.26	79.43
RIL-106	6.38	13.53	78.89	75.7	221	86.5	0.39	4.51	81.28
RIL-199	5.74	13.82	76.72	79.8	222.84	85.67	0.38	21.8	83.18
Mean	6.3	13.42	76.93	78.1	225.17	85.11	0.38	16.81	115.70

RELEASE OF THREE MAIZE GERMPLASM LINES FOR REDUCING PREHARVEST AFLATOXIN ACCUMULATIONS

INTRODUCTION

Zea mays (maize) is the largest food and feed crop produced globally, with grain production in 2008 exceeding 826 million Mg (FAOSTAT, 2010). The United States of America is the largest global maize producer, producing more than 307 Mg of maize with a value exceeding $49 billion dollars in 2008 (USDA NASS, 2010). Within the US, Texas was the 12th largest producer of maize with 0.89 million planted hectares, the largest production for any state outside of the temperate Midwest (USDA, 2010). Texas corn production occurs across very diverse production environments that extend in latitude from 26°N to 36° and range from subtropical production environments in South and Central Texas to temperate production environments in the High Plains of the Texas Panhandle.

A limiting factor in maize production in the Southern U.S. is chronic preharvest aflatoxin accumulation caused by *Aspergillus flavus*. The pathogen itself rarely causes economic yield losses but it can produce up to four different aflatoxins, B1, B2, G1 and G2. Collectively these compounds are known carcinogens and lethal if consumed in high concentrations (Castegnaro and McGregor, 1998; IARC, 2002). Additionally, chronic exposure to aflatoxin in both humans and livestock can lead to stunting, reduced growth and a myriad of other adverse health effects (Cardeilhac et al 1970; Lamplugh et al 1988; Gong et al 2008). Due to these facts, the US Food and

Drug Administration has issued limits on aflatoxin concentrations in corn: no more than 20 ng g^{-1} for food corn and no more than 300 ng g^{-1} for livestock feed (US FDA, 2010). These strict limits, combined with extensive testing, have minimized the presence of aflatoxin in the US food stream. However, these limits also produce significant economic losses to producers where aflatoxin occurs; they are forced to destroy their crops or sell them at significant loss. The exact economic loss to producers from aflatoxin contamination of corn is not well documented, but crop insurance payments to Texas producers for mycotoxin loss was $18 million in 2008 (USDA Risk Management Association, unpublished data) and direct losses across the United States have been estimated at $200 million per year (Texas Corn Producers Board, 2010).

Currently there are no known sources of immunity to aflatoxin accumulation. Consequently, there are no commercial maize hybrids with complete resistance. Conversely, there is a known range of susceptibilities of hybrids to aflatoxin accumulation and some sources of maize germplasm have been identified that reduce accumulations (Williams, 2006). Tropical germplasm has been identified as a good source for potential resistance to preharvest aflatoxin accumulation (Menkir et al, 2008). The pool of tropical germplasm available to evaluate for aflatoxin resistance is immense, as the genetic base of tropical maize is much broader than the temperate maize produced in the United States (Ochs, 2005). From diverse tropical material, germplasm lines with lower accumulation of aflatoxin than check lines have been recently identified and released, including Mp313E, Mp715, GT-MAS:gk, Mp717, Tx772, TZAR101-TZAR106 (Scott and Zummo, 1990; Scott and Zummo, 1992; McMillian et al, 1993; Williams and Windham, 2002; Llorente et al, 2004; Menkir et.al 2008).

Reduced aflatoxin accumulation in tropical miaze is associated with multiple traits which are often tested individually. These include improved husk coverage (Odvody et al, 1997), tighter husks (Betrán and Isakeit, 2004), improved kernel integrity (Odvody et al, 1997), harder kernel texture (Guo et al, 1995), improved drought and heat tolerance (Payne, 1992), maturity and adaptation (Betrán and Isakeit, 2002), and “factors” in the kernels which reduce fungal development or aflatoxin accumulation (Brown et al, 2001; Peethambran et al, 2010). Quantitative reductions in aflatoxin in tropical material are most likely a combination of these independent factors. Unfortunately tropical maize cultivars commonly lack adaptation and suitable agronomic performance to be used directly in hybrids for U.S. production environments. Specific limitations include delayed anthesis and maturity, unacceptably high ear height (Holland et al, 1996; Betrán et al, 2006a) and lower grain yield (Castillo-Gonzalez and Goodman, 1989). Breeding and selection to minimize these adaptive traits is necessary before the true value of the germplasm can be measured.

Historically, the Texas Agrilife Research maize improvement program has been a leader in the developing maize germplasm with reduced aflatoxin accumulation and has identified many sources of resistance with emphasis on tropical maize (Betrán et al, 2002; Ochs, 2005). The release of three maize germplasm lines, designated Tx736 (Reg. No. GP-___, PI___), and Tx 739 (Reg. No. GP-___, PI___) and Tx740 (Reg. No. GP-___, PI___) is proposed based on consistent reduction in aflatoxin accumulation compared to standard checks in line *per se* and hybrid combinations across multiple Texas environments that include heat and drought stress. While they are released as germplasm lines, they have improved agronomics typical of adapted material and thus have the potential of being directly tested in hybrid combinations.

MATERIALS AND METHODS

All lines were developed from intentional crosses using a modified pedigree method of plant breeding. Tx736 is a temperately derived line utilizing a first generation backcross with the pedigree of ((Tx772 x T246) x Tx772)-7-2-B-B-B-B-B-B-B. Tx772 is maize parent line released by the Texas Agricultural Experiment Station in 2003 because it has reduced aflatoxin accumulations (Llorente et al, 2004). T246 is a yellow grain maize germplasm line released by the Tennessee Agricultural Experiment Station in 1974 (Gerdes, et al. 1993). The single cross (Tx772 x T246) was made in the summer of 1996, with the backcross in the summer of 1997. Single ear to row progeny selection was then performed for two generations followed by seven generations of selfing two or more individual plants and making balanced bulks of these for planting the following year. Balanced bulks were created within a generation when selections of a few ears with a similar phenotype (kernel texture, grain color and cob color) were bulked together, these generations were designated a “B1 and B2”. This method was used because it has the simplicity of a bulk method while still “maintaining genetic variability” through heterogeneity of the pedigree method (Betrán et al, 2006a)

Lines Tx739 and Tx740 were selected from segregating S_3 plants of Agricomseeds’ heterotic groups A, C and E provided by Agricomseeds in Bolivia. Although this tropical population was strongly photoperiod sensitive, delayed flowering effects were minimized or eliminated by production in a short-day environment during the fall in Weslaco, TX (Castillo-Gonzalez and Goodman, 1989). Sixty-three single row plots were planted on August 26th 2002 in Weslaco (26° 09’ 48” N, 97°56’28”W) where the day length at that time is less than 13 hr d^{-1}. Initial selections were made on kernel texture and color (flint kernels and yellow to orange/bronze color). A total of 207 ears were selected and planted ear to row in College Station at the Texas AgriLife Research farm in Burleson County, TX (30°32”48”N, 96°26’00”W). Tx739 (LAMA2002-10-1-B-B-B) and Tx740 (LAMA2002-12-1-B-B-B) were selected for plant adaptation (plant and ear height, flowering synchrony and maturity) and kernel characteristics (texture, integrity and color) together with their superior performance in testcrosses with temperate testers.

Field Trials

Maize germplasm lines were evaluated in *per se* evaluations and in hybrid testcrosses. For testcross evaluation, all lines were crossed to LH195 (Corn States, St. Louis, MO). LH195 is a commercially used yellow dent grained parental line that belongs to the stiff stalk (SSS) heterotic group (Mikel and Dudley, 2006). LH195 has been used as a tester in this program to provide adequate separation in estimation of yield potential and for estimating aflatoxin accumulations in hybrid testcross (Betrán et al, 2005).

To estimate aflatoxin accumulation, trials were performed on Texas AgriLife Research farms near College Station, Corpus Christi and Weslaco, Texas and two on-farm trials located near Bardwell and Wharton, Texas. Not all of these lines were evaluated in the same trials each year. Each trial consisted of two or three replications arranged in an α-lattice design. To ensure consistent pathogen pressure, all plots were inoculated with *A. flavus*. Ten plants per replication at College Station, Weslaco, Bardwell and Wharton were inoculated using the silk channel method (Zummo and Scott, 1989). Plants at Corpus Christi were inoculated by placing *A. flavus* colonized kernels between the rows to allow for natural infection (Betrán et al., 2005). Inoculated ears were hand harvested, rated for fungal colonization and shelled. Bulked grain was ground with a Romer Mill (Romer Labs, Inc, Union, MO). Total aflatoxin accumulations were estimated using the USDA FGIS protocol of the Vicam Aflatest™ (Vicam, Watertown, MA).

Grain yield, grain moisture and test weight were estimated by combine harvesting plots with a John Deere 3300 combine set up for plot harvest by using a Harvest Master Grain Gauge H-1 (Juniper Systems, Logan, Utah) after the inoculated ears were hand harvested and adding the grain weights from hand harvested inoculated ears. Grain yield at Corpus Christi was estimated by hand harvesting all ears in the plot. Plant and ear height were measured as the height from the soil to the top of the tassel and to the ear node respectively. Ear height (EH) to plant height (PH) ratio (EPR) was calculated as EPR=EH/PH (Betrán et al, 2005). Days to anthesis and silking was measured from the day of planting until the 50% of the plants shed pollen or had silks exposed respectively. Kernel integrity was rated on a scale of 1-5 (1 = kernels with good integrity with few kernels broken or damaged and 5 = kernels with bad integrity, most kernels broken or damaged). Root lodging was measured as the percent of plants leaning past 30° off of vertical

Statistical Analysis

Data were analyzed using the Proc Mixed procedures in SAS 9.2. Orthogonal contrasts were obtained using the Contrast statement in conjunction with the Proc Mixed procedures in SAS 9.2. Aflatoxin accumulation data were transformed (logarithmic) to equalize the variances and standardize the data (Betrán et al, 2005).

CHARACTERISTICS

Tx736 is a temperate southern/sub-tropical adapted line that accumulates significantly lower amounts of aflatoxin than commercial hybrid checks when evaluated as a testcross with LH195. Across the five environments in 2005, Tx736 testcrosses accumulated 30% lower aflatoxin compared to the checks (Table 10), while during 2006 across two environments accumulated 73% lower aflatoxin compared to the checks (Table 11) Testcrosses of Tx736 were also lower in grain yield, and slightly higher in grain moisture, than commercial checks (Tables 10 and 11). Test weight was not different between Tx736 testcross and the commercial checks.

Tx739 and Tx740 evaluated for aflatoxin accumulations as inbred lines *per se* had lower aflatoxin accumulation than the average of other inbred lines in the trial (Table 12). Tx739 and Tx740 were later than temperate lines but similar to CML288, a resistant check. When evaluated as testcrosses with LH195, Tx739 and Tx740 also had lower aflatoxin accumulation than commercial checks (Tables 13 and 14). Grain yield was lower than commercial hybrids however and harvest moisture content increased 2.7-4.0% over the commercial hybrids.

Table 10. Analysis of variance and contrasts of Tx736 testcrosses for aflatoxin, grain yield, kernel traits, height, and flowering in 2005. A trial consisting of 25 entries was evaluated at Bardwell, College Station, Corpus Christi, Weslaco and Wharton, TX.

	DF[¶]	Aflatoxin	Log_{10} Aflatoxin	Test Weight	DF	Plant Height	Ear Height	EPR	DF	Grain Yield	DF	Grain Moisture
Genotype	24	516672**	0.86***	103.92***	24	465.97**	10685***	0.003*	24	149.14***	24	172.42***
Env	4	12114528***	14.38***	159.06	2	17319**	2720.16	0.007	5	1632.24***	3	1064.48***
Geno*Env	96	245548***	0.21***	35.63	48	199.46*	3598.39	0.002	120	115.15***	72	127.55***
Rep.(Env.)	10	312780**	0.30**	156.99***	5	906.35***	2124.06***	0.003	12	32.17***	8	41.95***
Residual	240	118387	0.12	33.38	120	129.1	8106.94	0.002	280	126.51	186	114.59
		Contrasts[‡]										
Tx736		400.73**	2.23***	74.07		248.43	89.49**	0.37*		5.08***		13.93***
Checks[‡]		574.64	2.48	72.34		263.66	109.66	0.41		6.90		12.14
Test		481.18	2.37	72.10		257.31	102.23	0.40		6.14		12.90

* Significant at .05 level
** Significant at .01 level
*** Significant at .001 level
[¶]Degrees of freedom for aflatoxin and grain moisture were measured at Bardwell, College Station, Corpus Christi, Weslaco and Wharton, TX, Degrees of freedom for Plant and ear height were measured at College Station and Weslaco, TX. Degrees of freedom for grain yield were measured at Bardwell, College Station, Corpus Christi, Hondo, Weslaco and Wharton, TX.
[†]Orthogonal contrast between Tx736 and checks as a whole. Designated significant by *, **, and *** described above.
[‡] Mean of the five hybrid checks (P31B13, P32R25, BH8913, DKC69-72 and W4700) included in the trial
Genotype*Environment interaction (Geno*Env); Replicate nested in environment Rep.(Env.)

Table 11. Analysis of variance and contrasts of Tx736 testcrosses for aflatoxin, grain yield, kernel traits and flowering in 2006. A trial consisting of 20 entries was evaluated at College Station, Corpus Christi and Weslaco, TX.

	DF[¶]	Aflatoxin	Log_{10} Aflatoxin	DF	Grain Yield	Grain Moisture	Test Weight	DF	Silk
Genotype	19	708120*	0.97***	19	7.38**	17.9***	87.9	19	3.60
Environment	2	6460121***	15.56***	1	263.77***	101.4***	2130.9	1	5589.68
Geno*Env	6	187579	0.34*	4	1.76	0.5	1.8	4	1.40
Rep(Entry)	38	301971***	0.23**	19	1.80*	1.6	60.4	19	1.27
Error	113	107677	0.13	73	1.03	1.1	65.5	76	0.86
					Contrasts[†]				
Tx736		173.89*	1.97**		7.75***	17.0*	82.5		71.00
Checks[‡]		628.95	2.64		10.06	15.6	81.9		70.60
Test Mean		479.33	2.34		7.92	15.6	78.3		70.03

* Significant at .05 level
** Significant at .01 level
*** Significant at .001 level
[¶]Degrees of freedom
[†] Orthogonal contrast between Tx736 and checks as a whole. Designated significant by *, ** and ***, described above.
[‡] Mean of the two hybrid checks (P31B13 and DKC69-71) included in the trial
Genotype*Environment interaction (Geno*Env); Replications nested within Entry (Rep(Entry))

Table 12. Analysis of variance and means of Tx739 and Tx740 lines per se for aflatoxin, kernel traits and flowering in 2003. A trial consisting of 32 entries was evaluated in Weslaco, TX.

	DF[¶]	Aflatoxin	Log_{10} Aflatoxin	Grain Texture	Kernel Integrity	Anthesis	Silking	ASI[†]
Entry	18	387490.61*	1.32**	4.72	1.67***	27.01***	19. 5***	2.24
Rep	3	433594.12	1.30*	18.48**	0.68	0.64	1.9	1.98
Bloc(Rep)	12	124449.25	0.48	16.00***	0.45	2.09	1.5	2.5
Error	42	196668.34	0.44	3.73	0.27	2.26	2.2	2.07
				Test means and separations				
Mean		342.82	2.00	2.16	2.14	70.22	72.3	2.3
$LSD_{.05}$		632.84	0.95	2.76	0.74	2.14	2.1	2.1
				Entry Means				
Tx739		114.0ab	2.01bcdefgh	1.25a	1.38ab	71.50bc	73.5bcd	2.0ab
Tx740		75.5ab	1.80abcdef	1.5a	2.25cde	73.50bc	74.5efg	1.0a
Tx732[†]		792.0c	2.80h	3.38ab	3.75g	66.00a	69.0a	3.0ab

* Significant at .05 level
** Significant at .01 level
*** Significant at .001 level
[¶] Degrees of freedom
[†] Anthesis Silking Interval
[‡] Tx732 was included as susceptible
Blocks nested in Replications (Bloc(Rep))

Table 13. Analysis of variance and contrasts of Tx739 and Tx740 testcrosses for aflatoxin in 2004. A trial consisting of 32 entries was evaluated in College Station and Weslaco, TX.

	DF[¶]	Aflatoxin	Log_{10} Aflatoxin
Genotype	30	444907*	0.67
Environment	1	78117	0.61
Geno*Env	30	241163	0.53
Rep(Env)	4	459028	1.17
Residual	118	220449	0.52
		Contrasts[†]	
Tx739		82.67*	1.64*
Tx740		88.50*	1.14***
Checks[‡]		637.77	2.47
Test Mean		305.61	2.04

* Significant at .05 level
*** Significant at .001 level
[¶]Degrees of freedom
[†] Orthogonal contrast between Tx739, Tx740, Tx741 and commercial checks as a whole. Designated significant by * and *** described above.
[‡] Mean of the five hybrid checks (DKC66-80, DK697, P31B13, P32R25 and LH195/LH210)included in the trial
Genotype*Environmental interaction (Geno*Env); Replication nested in environments (Rep(Env))

Table 14. Analysis of variance, means and contrasts of Tx739 and Tx740 testcrosses for aflatoxin, grain yield, lodging and kernel traits in 2005. A trial consisting of 30 entries was evaluated at College Station, Corpus Christi and Weslaco, TX.

	DF[¶]	Aflatoxin	Log_{10} Aflatoxin	Grain Yield	Kernel Integrity	DF	Root Lodging	Grain Moisture	Test Weight
Genotype	28	371020*	0.27	2.23**	2.21***	28	35.44	7.43***	4.88**
Environment	2	2797967***	2.02	817.92***	2.46	1	176.12	13.08	10.5
Geno*Env	56	213737	0.18*	0.96***	0.81	28	22.21	2.13***	1.87***
Rep(env)	6	714148*	0.52***	2.40***	2.29**	4	25.17	7.54***	1.49*
Residual	168	191562	0.12	0.44	0.58	112	17.28	0.45	0.47
					Contrasts[†]				
Tx739		355.44*	2.38*	5.30*	2.22***		3.51	16.05***	75.49
Tx740		365.33*	2.32**	5.54*	2.67*		4.69	16.55***	76.25
Check Mean[‡]		811.85	2.76	6.34	3.43		1.29	12.56	75.24
Test Mean		491.41	2.51	5.50	2.54		3.48	14.61	75.84

* Significant at .05 level
** Significant at .01 level
*** Significant at .001 level
[¶]Degrees of freedom
[†] Orthogonal contrast between Tx739, Tx740, Tx741 and commercial checks as a whole. Designated significant by * described above.
[‡] Mean of the four hybrid checks (P31B13, P32R25, DKC69-70 and DKC69-72) included in the trial
Genotype*Environment interaction (Geno*Env); Replications nested in Environments (Rep(Env))

DISCUSSION

Several sources of tropical and temperate germplasm with reduced aflatoxin accumulation have been previously released. These include Mp313E, Mp714, Mp716, Tx772, GT601, GT602, TZAR101-TZAR106 (Scott and Zummo, 1990; Scott and Zummo, 1992; McMllian et al, 1993; Williams and Windham, 2001; Llorente et. al, 2004; Menkir et. al, 2008; Guo et al, 2010). Each set of germplasm released targeting aflatoxin reduction has provided unique genetic backgrounds, agronomic traits and environments of adaptation. The addition of more unique germplasm sources of reducing aflatoxin accumulations in maize may help to identify underlying pathways and allow the pyramiding of durable sources of resistance.

There are many agronomic traits these lines have that cause the reduced aflatoxin accumulations. These include improved husk coverage, increased grain hardness, maintenance of kernel integrity, and others (Odvody et al, 1997; Betrán et al, 2006a). In our tests Tx739 and Tx740 testcrosses had higher grain moisture content than the commercial hybrids. This higher moisture content is likely caused by a combination of increased husk coverage and later flowering date. These two traits are common in tropical maize compared to temperate maize; their presence should be acceptable for maize grown in areas with longer growing seasons such as Texas (Betrán et al, 2006a). Although husk coverage was not specifically measured in trials with Tx739 and Tx740, both testcrosses and the inbred lines have husks which are tight and extend past the tip of the ear. Tx739 and Tx740 also had improved kernel integrity compared to the commercial checks (Table 14).

All of the inbreds had reduced aflatoxin accumulations relative to the commercial hybrids that were evaluated under our various inoculated field conditions, which often included drought and heat stress. Testcrosses of Tx736, TX739 and Tx740 did not show grain yield equal to the commercial hybrids used as checks, but each of these lines in testcross produced grain with reduced aflatoxin accumulation which would often be the difference between selling and destroying grain for producers. We expect these sources of germplasm will be useful to programs that are developing high yielding and adapted maize hybrids with consistently reduced aflatoxin accumulation.

AVAILABILITY

Seed for Tx736, Tx739 and Tx740 will be maintained by the Quantitative Genetics and Maize Breeding Program of Texas AgriLife Research at College Station, TX. Seed of this material has also been deposited in the National Plant Germplasm System. Seed will be available with a Materials Transfer Agreement (MTA) from the Office of Technology Commercialization, Texas A&M University System, 1700 Research Parkway, Suite 250, College Station, TX 77845-9548.

CONCLUSIONS

Aflatoxin remains a significant problem in Texas, the Southern United States, and many corn growing regions of the world partly because it is extremely challenging to identify and accumulate genetic components that improve host plant resistance to aflatoxin accumulation. These three lines, Tx736, Tx739 and Tx740 will serve as sources for quantitative aflatoxin resistance that may be pyramided with other sources of resistance and locally adapted material to ultimately create locally adapted varieties and hybrids with a lower risk of aflatoxin accumulations.

SUMMARY

There remains a need to reduce or eliminate the problem of preharvest aflatoxin contamination in maize. Genetic resistance to infection by the pathogen or the production of its toxin is appealing approach to this problem and there has been much research to identify maize germplasm and traits of maize to reduce aflatoxin accumulations. Tropical maize germplasm has been identified as a pool of germplasm which contains genes that contribute to reduced aflatoxin accumulations. Reduced aflatoxin is related to traits typically found in tropical maize, which include long and tight husks, hard kernel textures and good kernel integrity. Several other studies have identified QTL for reducing preharvest aflatoxins in maize (Paul et al, 2003; Brooks et al, 2005; Bello, 2007 and Warburton et al, 2009). With the exception of Bello (2007), there are no reports of simultaneous aflatoxin accumulation, agronomic performance or potential desirability evaluations of the mapping populations in hybrids. Furthermore several of the RILs should be crossed with more testers, in order to reduce the heterotic group limitation and to estimate the true possible benefits to producers. The use of hybrids in maize for estimation QTL is beneficial to identifying those QTL which are most important to producers. Of the sources of maize germplasm identified to reduce aflatoxin accumulations, most of it lacks the adequate performance to be used directly in commercial hybrids (Scott and Zummo, 1990; Scott and Zummo, 1992; McMllian et al, 1993; Williams and Windham, 2001; Betrán et. al, 2004; Menkir et. al, 2008; Guo et al, 2010). Three studies were conducted with the ultimate goal of reducing aflatoxin and increasing yields in Texas.

First, a set of recombinant inbred lines (RILs) derived from the cross of B73*o2o2* x CML161 was testcrossed to a temperate maize line (LH195) in an effort to estimate QTL for aflatoxin resistance and other traits in testcross. Across the five environments in which the trial was grown, a total of 96 QTL were detected across all traits measured including aflatoxin, anthesis and silking dates, plant and ear height, oil, protein and starch content and grain yield. A total of 10 QTL were detected affecting aflatoxin accumulation with the favorable alleles derived from the CML161 parent. One of the QTL detected in the hybrid testcrosses co-located to the same region as QTL detected in *per se* evaluations. This QTL merits additional study as it appears to be the most relevant in the reduction of aflatoxin, in this population.

Grain yield was measured in two subsets of RIL testcrosses in 2008 and 2009 had seven RIL testcrosses observed during both years. None of the RIL testcrosses produced as much grain as the commercial hybrids included in the trial; however, several testcrosses did perform within 10% (2008) and 17% (2009) of the commercial hybrids included as checks. This reduced grain yield was unsurprising as the RILs were derived from a temperate x tropical cross and the tester used was of the same heterotic group as the temperate parent line. However, a different tester may provide improved agronomic performance in these and other RILs.

New sources of maize germplasm were developed, identified and released to breed maize for reduced aflatoxin accumulations. Testcrosses with these germplasm sources accumulated significantly fewer aflatoxins than the commercial hybrids included in the trials. These new germplasm sources are derived from tropical and temperate x exotic materials. Release of these exotic/tropical maize lines will allow for other researchers to introduce these exotic alleles into their programs and breed maize with reduced aflatoxin accumulations.

The combination of knowledge gained from this research should help researchers pursuing reduced preharvest aflatoxin accumulations in maize. In addition to the reduction in aflatoxin, agronomic traits measured in these studies need to be incorporated in germplasm identified to reduce aflatoxins, in an effort to make the germplasm more agronomically desirable and readily useable by producers.

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APPENDICES

Appendix 1. Phenotypic data for aflatoxin trial at College Station during 2008.

RIL	Aflatoxin	Log Aflatoxin	Grain Yield	Grain Moist	Days to Silk	Oil	Protein	Starch	Plant Heigt	Ear Height	Stay Green	Root Lodging
	ppb		tn/ha	%	Days	%	%	%	cm	cm	1-5	%
RIL-1	187.96	2.20	4.22	13.50	85.00	2.88	10.97	72.89	241.81	102.95	2.59	9.12
RIL-2	118.67	2.06	5.30	14.90	84.67	3.46	11.34	71.64	232.45	99.20	3.64	6.05
RIL-3	138.67	2.06	5.71	15.53	84.00	2.96	10.77	72.71	241.11	94.44	2.61	5.67
RIL-7	157.46	2.15	5.01	13.65	82.00	3.15	11.55	71.73	245.91	104.17	3.05	6.73
RIL-9	73.33	1.82	4.22	15.53	82.67	3.22	11.47	71.64	227.72	94.54	2.92	1.40
RIL-10	286.33	2.32	4.70	13.80	84.33	2.76	11.77	71.62	249.17	102.92	3.88	7.25
RIL-11	33.33	1.24	4.48	14.10	84.67	2.88	11.07	72.69	237.31	89.84	3.39	4.73
RIL-21	76.67	1.88	4.66	14.80	83.67	2.88	11.55	71.99	239.88	97.42	3.28	3.88
RIL-23	35.33	1.52	4.90	14.23	84.33	3.31	11.28	71.53	245.35	104.96	3.04	0.98
RIL-28	116.00	1.90	5.16	14.97	82.33	2.96	10.99	72.14	238.12	101.90	3.79	7.11
RIL-31	129.67	1.88	5.05	14.37	84.33	2.83	11.64	72.22	241.86	93.50	3.33	1.25
RIL-37	60.67	1.59	4.52	14.50	82.67	3.03	11.59	71.98	235.65	83.46	3.58	7.30
RIL-39	31.00	1.35	4.77	15.13	81.33	2.72	11.10	72.71	232.00	94.68	3.62	15.25
RIL-41	128.33	2.06	5.18	14.30	84.67	3.05	10.83	72.39	235.45	94.43	2.90	0.47
RIL-42	79.00	1.84	5.17	14.80	83.67	3.33	11.58	71.57	248.57	99.06	3.00	1.85
RIL-44	190.00	2.24	5.31	13.90	82.67	2.89	11.42	72.39	242.30	99.99	2.77	9.76
RIL-45	54.33	1.67	4.64	13.85	83.67	2.82	11.13	72.43	233.02	98.80	3.14	5.53
RIL-54	106.00	2.02	4.01	15.03	85.00	2.81	11.04	72.91	231.04	92.54	3.16	0.00
RIL-56	53.67	1.49	5.19	15.00	82.00	3.18	11.10	72.28	239.03	100.93	2.59	4.05
RIL-57	121.67	1.95	4.05	14.23	85.33	2.98	11.44	72.34	238.70	96.25	2.73	9.42
RIL-59	45.00	1.52	5.43	15.07	83.67	3.50	11.88	70.70	252.02	97.68	2.81	5.49
RIL-61	45.33	1.37	4.60	13.97	84.33	2.88	10.75	72.96	231.36	98.88	3.23	2.43
RIL-63	136.67	2.11	4.12	15.63	84.00	2.76	11.39	72.40	227.70	92.11	3.49	4.60
RIL-64	92.00	1.84	4.81	14.50	83.00	3.31	11.03	71.93	240.84	104.92	3.31	2.48
RIL-67	37.33	1.55	4.93	14.27	83.00	3.03	11.07	72.56	237.57	97.58	3.19	22.99
RIL-68	127.46	2.02	4.58	14.60	84.00	2.90	11.55	72.18	237.75	91.01	2.74	3.29
RIL-72	74.96	1.75	4.38	18.40	84.50	2.94	10.89	72.91	237.63	95.73	3.96	1.76
RIL-75	56.33	1.58	5.11	14.97	81.67	3.22	11.78	71.50	243.08	92.57	2.80	3.34
RIL-76	62.96	1.80	4.61	14.75	83.50	2.94	10.65	72.85	244.06	96.39	4.03	2.99

Appendix 1. (continued).

RIL	Aflatoxin	Log Aflatoxin	Grain Yield	Grain Moist	Days to Silk	Oil	Protein	Starch	Plant Heigt	Ear Height	Stay Green	Root Lodging
	ppb		tn/ha	%	Days	%	%	%	cm	cm	1-5	%
RIL-80	326.67	2.47	4.55	15.03	85.00	3.39	10.86	71.84	233.15	84.96	3.16	1.57
RIL-82	61.33	1.75	5.49	13.30	82.00	2.75	11.49	72.23	248.37	111.10	3.48	21.36
RIL-85	180.00	2.25	5.06	15.37	84.33	2.75	11.04	72.74	232.57	94.81	3.42	5.92
RIL-88	77.00	1.38	4.74	15.57	82.67	3.42	11.76	71.05	230.06	94.94	3.37	11.00
BH9012	55.00	1.66	6.54	14.03	81.67	2.96	10.86	72.74	247.96	90.98	3.33	4.68
RIL-91	34.00	1.45	6.09	15.80	83.33	3.49	9.86	71.96	251.17	112.51	2.48	3.39
RIL-92	43.00	1.59	5.67	14.23	82.33	3.35	11.13	71.95	228.78	92.64	3.17	7.21
RIL-97	83.33	1.86	3.74	15.13	84.00	2.78	11.64	72.19	173.59	127.10	3.27	1.69
RIL-99	326.67	2.49	4.06	15.13	83.33	2.54	11.09	72.90	227.56	90.43	2.52	0.00
RIL-101	104.33	1.84	4.27	14.43	82.33	3.29	11.61	71.68	234.68	97.61	4.21	1.29
RIL-102	280.00	2.43	3.16	15.40	84.00	3.08	11.07	72.50	236.24	97.42	4.01	4.93
RIL-105	87.00	1.83	3.28	14.20	83.00	3.36	11.53	71.23	225.79	81.05	2.34	0.47
RIL-106	94.33	1.89	4.52	15.20	82.67	2.41	12.59	71.92	241.54	87.79	2.99	5.14
RIL-109	21.67	1.30	4.32	14.13	84.67	3.24	11.60	71.50	232.50	102.38	3.62	7.36
RIL-111	219.33	1.97	3.93	14.17	83.00	3.05	11.77	71.74	250.25	98.66	4.62	10.83
RIL-112	110.67	2.04	4.61	14.60	84.00	3.13	11.19	72.18	232.18	89.73	2.74	4.37
RIL-113	131.33	2.09	5.16	14.43	82.67	3.44	10.95	71.97	228.51	95.61	1.78	6.02
RIL-114	125.00	2.07	4.55	15.30	84.00	3.16	11.98	71.32	228.69	90.45	2.92	2.72
RIL-115	12.00	0.90	4.68	14.67	82.67	3.04	12.35	71.06	231.88	86.05	3.33	1.88
RIL-116	97.67	1.87	4.38	13.43	84.67	3.03	11.61	71.90	231.80	86.38	2.69	2.18
RIL-118	38.33	1.50	4.27	14.77	85.00	3.42	12.03	70.96	237.14	93.63	3.59	24.05
RIL-122	151.00	2.08	5.09	15.07	83.67	3.22	11.18	72.25	237.29	97.98	3.24	1.70
RIL-123	99.67	1.99	5.39	13.33	81.33	2.89	11.87	71.80	235.62	90.36	3.32	3.63
DKC 66-80	169.00	1.74	7.36	15.63	82.67	3.09	10.88	72.09	242.78	92.04	2.64	1.73
RIL-127	94.67	1.96	3.56	15.80	82.67	3.05	10.48	71.95	233.19	83.60	3.18	7.70
RIL-132	119.67	1.98	4.09	15.17	83.33	2.91	11.89	71.58	233.55	97.32	3.33	5.74
RIL-133	25.33	0.97	4.63	15.27	83.00	2.73	10.48	73.12	230.33	91.07	3.89	8.66
RIL-134	133.33	1.99	5.01	14.77	84.33	3.30	11.40	71.75	250.67	104.53	2.91	2.35
RIL-135	94.00	1.88	4.45	15.20	84.67	2.88	11.65	72.15	249.06	108.66	3.14	7.51
RIL-137	61.67	1.68	5.50	15.93	84.00	3.51	11.63	71.07	263.58	114.96	2.82	2.23
RIL-138	263.33	2.39	5.09	14.00	84.33	2.73	11.55	72.40	238.60	96.89	3.38	6.99

Appendix 1. (continued).

RIL	Aflatoxin	Log Aflatoxin	Grain Yield	Grain Moist	Days to Silk	Oil	Protein	Starch	Plant Heigt	Ear Height	Stay Green	Root Lodging
	ppb		tn/ha	%	Days	%	%	%	cm	cm	1-5	%
RIL-140	39.00	1.28	4.77	14.57	83.67	3.54	11.39	71.64	243.22	85.40	2.82	1.95
RIL-141	98.00	1.44	4.89	14.73	82.67	3.18	12.11	71.14	240.47	89.74	3.58	22.79
RIL-144	257.67	2.31	5.35	15.43	82.67	3.02	11.83	71.65	259.59	111.17	3.48	1.08
RIL-145	82.00	1.74	5.37	15.17	83.33	2.82	11.80	71.79	256.04	100.62	3.44	7.31
RIL-147	115.00	1.66	4.70	15.23	82.67	3.16	11.87	71.37	235.47	93.66	3.27	2.24
RIL-150	111.67	1.98	5.49	14.93	83.33	3.21	11.12	72.12	229.37	81.48	2.44	3.26
RIL-151	54.67	1.58	4.29	14.13	82.00	3.02	11.12	72.38	225.32	89.84	3.16	2.98
RIL-153	148.33	1.86	4.68	15.53	83.00	3.13	11.13	72.17	241.13	93.58	3.72	0.70
RIL-154	122.33	1.92	4.94	15.23	83.00	2.67	10.68	73.43	241.75	100.88	3.54	2.10
RIL-156	174.96	2.22	4.15	13.27	83.33	2.48	11.31	72.73	236.30	97.06	3.24	7.55
RIL-157	131.33	2.08	4.46	14.47	84.00	2.78	11.54	72.15	244.80	100.49	3.85	8.99
RIL-158	165.33	1.99	5.12	16.67	83.67	3.07	11.07	72.23	235.85	88.03	2.98	4.46
RIL-162	226.67	2.35	4.52	15.57	84.00	2.89	11.55	72.36	229.15	90.83	2.86	0.79
RIL-165	39.33	1.54	5.64	14.40	83.00	2.90	10.94	72.66	258.05	107.02	2.68	1.18
RIL-170	64.33	1.77	4.54	15.67	83.67	3.18	11.74	71.39	232.18	101.65	3.36	17.52
RIL-172	106.00	2.01	5.26	17.60	83.00	2.98	10.91	72.62	251.43	100.29	2.84	1.52
RIL-173	56.67	1.55	4.93	14.57	84.00	3.28	10.98	72.10	234.11	90.53	3.66	7.47
RIL-174	82.67	1.87	5.91	14.67	83.67	3.28	10.57	72.73	245.25	99.21	3.11	2.05
RIL-175	149.00	2.15	3.90	13.40	84.00	3.35	10.89	72.03	231.93	89.68	3.16	15.14
RIL-177	89.67	1.90	4.55	13.10	83.67	3.09	11.08	72.12	242.88	101.16	3.71	10.03
RIL-178	66.53	1.62	3.90	14.73	83.00	3.24	11.62	71.41	241.05	99.64	2.97	3.93
RIL-180	46.33	1.21	5.41	16.07	83.67	3.53	11.55	71.52	230.75	93.84	2.46	0.10
RIL-184	32.33	1.51	3.72	14.30	83.67	3.17	11.88	71.49	243.51	103.29	3.04	5.94
RIL-185	163.33	2.20	5.01	13.07	82.67	2.84	11.11	72.51	229.77	95.95	3.17	6.62
RIL-186	100.33	1.92	4.13	13.97	83.33	3.20	11.12	72.32	231.92	95.55	2.52	1.54
RIL-187	64.67	1.69	4.36	14.73	83.33	3.21	10.86	72.48	257.82	108.16	3.10	5.38
RIL-190	43.67	1.58	5.73	15.37	83.00	3.62	11.49	71.11	235.61	102.02	2.07	4.95
RIL-192	125.00	2.07	4.75	14.77	84.00	2.73	11.81	72.31	250.66	96.39	3.17	5.09
RIL-195	528.33	2.38	5.48	13.73	83.67	3.33	11.54	71.53	230.66	95.30	3.09	2.89
RIL-198	65.67	1.64	4.69	14.57	83.67	3.06	11.80	71.71	239.50	87.23	2.49	4.92
RIL-199	45.33	1.62	5.41	14.40	83.33	3.03	10.64	72.84	233.67	98.90	2.68	6.78

Appendix 1. (continued).

RIL	Aflatoxin	Log Aflatoxin	Grain Yield	Grain Moist	Days to Silk	Oil	Protein	Starch	Plant Heigt	Ear Height	Stay Green	Root Lodging
	ppb		tn/ha	%	Days	%	%	%	cm	cm	1-5	%
RIL-203	154.67	2.15	5.16	13.57	82.67	2.77	11.23	72.42	244.30	101.46	3.22	20.93
RIL-205	103.67	1.72	4.54	14.80	81.33	2.82	10.96	72.63	235.23	96.46	2.88	15.85
RIL-207	82.67	1.89	4.55	14.60	83.67	3.23	11.20	72.03	217.82	81.19	3.02	2.23
RIL-208	95.00	1.92	4.93	13.57	83.33	3.60	11.09	71.52	227.69	85.69	3.22	1.01
RIL-212	34.67	1.37	4.61	15.13	83.67	2.94	11.66	72.08	234.53	90.74	3.62	1.95
RIL-213	190.00	2.26	5.45	14.80	83.00	3.27	11.47	71.68	232.70	93.36	2.82	3.96
RIL-216	89.33	1.85	5.80	13.90	84.00	3.18	11.52	71.63	234.20	81.11	3.03	1.33
RIL-217	286.67	2.25	4.29	14.70	84.33	2.91	11.36	72.09	237.71	83.35	3.37	4.72
RIL-220	54.33	1.67	5.27	14.27	83.00	2.70	11.46	72.64	236.66	94.53	3.64	0.00
RIL-221	97.00	1.96	4.20	15.70	85.00	3.68	11.16	71.43	216.52	87.21	2.86	7.76
RIL-222	96.67	1.65	5.21	14.60	83.33	2.95	11.37	71.94	242.72	92.93	2.78	2.15
RIL-225	116.67	2.06	4.60	15.60	83.67	3.39	11.33	71.72	233.65	97.02	2.60	2.99
RIL-226	71.33	1.72	4.69	14.53	81.33	3.19	11.41	71.71	236.63	92.49	3.74	1.57
RIL-229	59.33	1.45	5.51	15.50	84.33	3.49	11.36	71.15	252.67	105.04	2.69	2.61
RIL-232	131.33	2.07	5.46	14.87	82.33	3.01	12.09	71.25	249.37	93.99	3.14	2.85
RIL-233	400.00	2.55	5.22	14.93	84.00	3.12	11.49	71.80	226.48	94.86	2.74	2.60
RIL-237	98.00	1.98	4.48	14.83	84.33	3.09	11.62	71.91	238.52	101.04	3.50	1.23
RIL-239	49.00	1.59	6.33	14.87	82.67	3.36	10.94	72.00	248.56	87.57	2.27	1.55
RIL-241	45.00	1.50	5.45	15.57	82.33	3.34	11.36	71.39	231.59	87.61	3.52	1.19
RIL-243	128.00	1.69	5.08	13.77	83.00	3.02	11.03	72.28	242.58	96.68	3.31	0.06
RIL-244	77.33	1.84	5.74	16.03	83.00	3.38	11.50	71.60	236.71	102.33	2.44	2.33
RIL-247	57.67	1.71	5.25	14.70	83.67	3.51	11.62	70.97	246.74	96.14	1.80	0.45
RIL-250	97.67	1.98	4.97	15.30	84.00	3.32	11.58	71.44	233.78	90.91	2.66	1.29
RIL-251	90.33	1.80	4.30	13.50	84.33	3.12	11.36	71.95	239.98	94.64	2.96	0.68
RIL-255	191.67	2.12	3.95	13.90	85.00	2.94	11.51	72.21	222.09	86.00	3.17	0.61
RIL-256	138.67	2.10	4.12	14.93	85.00	3.04	11.25	72.40	218.66	80.48	3.17	2.15
RIL-259	443.33	2.49	4.63	14.33	83.00	3.26	12.25	70.79	240.80	96.47	2.62	2.15
RIL-260	303.33	2.43	5.00	15.87	83.33	2.49	11.89	72.51	240.90	98.52	2.87	0.00
RIL-261	75.67	1.59	4.93	14.40	82.67	3.07	11.89	71.43	235.97	90.32	2.43	1.79
RIL-262	68.67	1.81	4.98	14.65	84.00	3.16	11.19	72.21	231.59	85.75	2.30	1.16
RIL-266	151.46	2.01	5.07	14.40	84.00	3.08	11.63	71.47	247.49	94.31	3.06	1.02

Appendix 1. (continued).

RIL	Aflatoxin	Log Aflatoxin	Grain Yield	Grain Moist	Days to Silk	Oil	Protein	Starch	Plant Heigt	Ear Height	Stay Green	Root Lodging
	ppb		tn/ha	%	Days	%	%	%	cm	cm	1-5	%
RIL-268	161.33	2.08	4.47	14.80	84.67	2.89	11.29	72.29	234.13	89.35	2.78	4.12
RIL-269	132.67	1.94	4.12	13.97	84.67	2.50	11.28	73.28	246.98	103.81	3.21	7.62
RIL-272	74.00	1.87	5.45	16.33	83.33	2.91	11.32	72.60	235.28	101.99	2.56	0.15
RIL-274	74.33	1.59	4.21	15.27	85.00	2.41	11.24	73.22	241.15	105.48	3.13	1.22
RIL-275	88.33	1.88	4.53	13.77	84.00	3.34	11.91	71.37	235.39	102.14	3.65	10.02
RIL-276	71.67	1.79	4.53	14.50	84.67	3.44	10.37	71.56	231.01	95.72	2.98	1.93
RIL-277	508.67	2.20	4.04	15.40	84.67	3.31	11.47	71.67	229.21	93.50	2.71	0.68
RIL-279	52.67	1.64	5.27	15.00	84.00	3.30	11.60	71.54	233.34	98.51	2.82	7.21
RIL-280	38.00	1.53	4.50	13.73	83.67	2.72	10.79	73.04	240.33	94.15	3.58	1.46
RIL-281	177.67	1.84	4.23	15.33	83.33	2.64	11.01	73.02	241.48	87.33	3.06	2.11
RIL-282	44.00	1.50	5.32	13.73	81.33	3.05	11.99	71.46	244.97	98.94	3.25	2.54
RIL-283	72.33	1.86	4.99	14.53	84.00	2.75	12.24	71.57	245.43	105.32	4.19	9.35
RIL-285	69.67	1.77	5.29	15.03	83.00	3.35	12.02	70.78	253.27	101.74	2.95	0.65
RIL-286	64.00	1.75	4.65	14.27	83.67	3.42	11.41	71.52	230.53	100.19	3.17	6.36
CML161/LH195	33.00	1.45	6.32	15.53	82.33	3.37	10.99	71.89	252.79	103.72	2.27	10.62
B73 o2/LH195	180.00	2.25	3.24	14.83	84.67	3.12	11.55	71.79	219.27	78.31	3.07	5.06
P31B13	86.67	1.82	7.63	15.87	80.00	3.00	9.99	73.08	250.45	100.43	2.58	4.42
B73 o2/LH195	133.33	2.12	3.19	14.37	85.33	3.12	11.58	71.89	223.27	78.75	3.21	4.61

Appendix 2. Phenotypic data for aflatoxin trial at Weslaco, TX during 2008.

RIL	Days to Silk	Days to Anthesis	ASI	Aflatoxin	Log Aflatoxin	GY	Grain Moist	Oil	Protein	Starch	Plant height	Ear Height	EPR	Stalk Lodge	Nodded Ear
	d	d	d	ppb		tn/ha	%	%	%	%	cm	cm		%	%
RIL-1	79.1	76.6	1.67	337.51	2.46	3.42	14.67	3.58	12.27	70.26	190.74	56.73	0.30	0.00	9.97
RIL-2	76.1	74.3	2.00	663.83	2.66	4.83	14.76	4.18	10.74	70.58	194.60	55.03	0.28	0.00	7.04
RIL-3	75.9	74.6	1.33	295.67	2.44	5.41	15.03	3.79	10.36	71.23	173.32	61.81	0.36	0.37	16.34
RIL-7	76.2	75.2	0.67	556.95	2.75	5.67	14.59	3.87	10.87	70.87	202.02	65.63	0.33	0.00	10.04
RIL-9	75.2	75.3	0.00	507.69	2.66	3.88	15.65	3.81	11.07	70.87	183.64	56.73	0.31	0.00	13.23
RIL-10	76.0	74.4	2.00	826.32	2.85	4.73	14.89	3.90	11.68	69.95	198.15	67.73	0.34	0.40	5.78
RIL-11	75.3	74.2	1.33	699.31	2.68	4.75	16.38	3.84	10.65	71.33	195.21	56.73	0.29	0.37	12.64
RIL-21	75.4	74.8	0.67	434.18	2.52	5.12	13.90	3.59	11.90	70.50	194.79	60.11	0.31	0.43	13.57
RIL-23	76.6	76.3	0.00	297.43	2.27	5.41	15.29	3.61	11.01	71.30	196.95	56.73	0.29	0.90	4.79
RIL-28	76.2	74.4	2.00	641.20	2.79	5.19	15.02	3.61	10.40	71.29	185.54	60.11	0.33	1.50	10.56
RIL-31	77.9	75.6	2.00	131.98	2.11	5.22	15.29	3.31	11.70	71.27	191.81	61.81	0.32	0.43	6.38
RIL-37	76.0	74.3	2.00	412.61	2.57	5.61	14.89	3.69	11.08	70.97	182.79	52.49	0.29	0.43	19.13
RIL-39	75.4	74.4	1.33	107.97	2.01	5.07	15.27	3.53	10.83	71.37	180.44	55.88	0.31	0.43	12.96
RIL-41	75.5	74.9	0.67	755.79	2.73	4.55	14.66	3.44	10.50	71.67	198.37	57.57	0.29	0.00	22.84
RIL-42	76.8	74.9	2.00	251.74	2.38	5.24	14.58	3.75	11.99	70.66	184.81	59.27	0.32	0.43	13.29
RIL-44	75.3	74.1	1.33	640.84	2.80	4.73	15.43	3.46	10.55	71.42	193.74	63.50	0.33	1.93	27.78
RIL-45	76.1	74.8	1.33	519.78	2.44	4.44	14.28	3.50	10.85	71.43	187.87	57.57	0.31	0.43	9.47
RIL-54	76.8	75.4	1.33	267.24	2.38	3.58	14.93	3.30	11.54	71.70	188.27	56.73	0.30	0.00	10.71
RIL-56	75.5	74.9	0.67	250.46	2.37	4.36	15.24	3.87	11.59	70.55	190.35	58.42	0.31	0.00	13.42
RIL-57	77.4	75.7	1.33	2064.12	3.07	4.38	14.62	3.36	11.25	71.41	178.72	58.42	0.33	0.43	10.91
RIL-59	76.0	74.2	2.00	225.73	2.33	5.83	15.12	4.09	11.62	69.94	198.94	44.87	0.23	0.37	14.43
RIL-61	76.2	74.3	2.00	380.01	2.35	4.61	15.00	3.79	10.73	71.29	183.87	58.42	0.32	0.00	6.89
RIL-63	76.7	75.3	1.33	360.37	2.55	4.27	14.94	3.87	11.03	70.91	193.96	59.27	0.30	0.00	14.29
RIL-64	76.0	74.9	1.33	196.90	2.22	4.52	15.25	4.01	10.91	71.11	187.21	55.88	0.30	0.37	14.44
RIL-67	79.9	76.6	2.67	237.85	2.35	3.68	15.03	3.49	10.95	71.68	184.77	59.27	0.32	0.63	20.23
RIL-68	76.1	75.0	0.67	131.44	2.18	5.12	13.66	3.76	11.10	71.05	186.69	64.36	0.34	0.47	7.42
RIL-72	77.2	75.6	0.67	694.92	2.79	5.22	15.04	3.45	10.41	71.71	190.38	58.01	0.30	0.52	26.66
RIL-75	75.8	74.2	2.00	479.71	2.65	4.53	14.75	3.81	12.06	70.25	182.69	60.11	0.33	1.43	6.18

Appendix 2. (continued).

RIL	Days to Silk	Days to Anthesis	ASI	Aflatoxin	Log Aflatoxin	GY	Grain Moist	Oil	Protein	Starch	Plant height	Ear Height	EPR	Stalk Lodge	Nodded Ear
	d	d	d	ppb		tn/ha	%	%	%	%	cm	cm		%	%
RIL-76	77.0	74.9	1.67	363.99	2.55	5.41	15.54	4.12	10.52	70.76	192.66	61.82	0.32	0.00	7.08
RIL-80	77.3	75.8	1.33	1176.47	3.04	3.78	14.49	3.53	10.95	71.58	182.74	57.57	0.32	0.43	10.03
RIL-82	75.5	74.5	1.33	786.38	2.85	5.55	15.29	3.70	11.19	70.81	194.02	63.50	0.33	0.00	16.19
RIL-85	77.1	75.4	1.33	419.74	2.62	4.50	15.03	3.70	10.24	71.52	189.80	60.11	0.32	1.23	14.59
RIL-88	75.9	74.7	1.33	373.44	2.57	4.19	14.84	4.22	11.31	70.17	181.82	54.19	0.30	0.50	14.15
BH9012	76.0	75.9	0.00	231.57	2.33	5.22	15.63	3.79	10.06	71.45	186.31	60.11	0.32	0.00	12.91
RIL-91	76.7	75.3	1.33	378.28	2.54	5.82	15.27	4.24	9.91	71.13	204.12	60.11	0.30	1.17	10.96
RIL-92	75.2	74.6	0.67	1081.18	2.42	5.09	15.08	3.86	11.57	70.58	187.60	60.96	0.33	0.37	11.34
RIL-97	77.4	75.8	1.33	796.92	2.73	4.92	15.81	3.86	11.45	70.74	170.32	53.34	0.31	0.80	13.30
RIL-99	77.4	75.1	2.00	689.90	2.81	4.57	15.19	3.50	10.76	71.54	194.99	61.81	0.32	0.00	8.16
RIL-101	76.6	74.7	2.00	136.54	2.07	4.30	15.45	4.07	11.22	70.61	190.91	57.57	0.30	0.80	2.58
RIL-102	78.0	75.8	2.00	578.11	2.65	3.59	14.85	3.58	10.12	72.02	203.65	59.27	0.29	0.93	9.05
RIL-105	75.9	74.2	1.67	287.37	2.42	6.30	15.38	4.21	9.45	71.33	188.96	51.66	0.27	2.17	25.12
RIL-106	75.9	74.2	2.00	285.93	2.45	5.97	15.46	3.53	10.79	71.57	174.28	60.96	0.35	2.70	7.80
RIL-109	77.4	75.7	1.33	203.75	2.22	3.48	14.30	3.54	10.82	71.42	185.44	60.11	0.32	0.00	10.68
RIL-111	76.0	74.4	2.00	296.04	2.43	4.44	14.51	3.89	12.05	70.21	193.10	57.57	0.30	0.00	9.10
RIL-112	76.8	76.0	0.67	406.40	2.49	4.20	15.05	3.95	10.99	71.02	182.92	62.65	0.34	0.00	3.45
RIL-113	74.8	74.4	0.67	672.28	2.78	4.97	14.90	3.62	11.89	70.68	184.63	57.57	0.31	0.00	7.21
RIL-114	77.3	75.8	1.33	643.54	2.77	4.09	13.64	3.42	11.66	71.23	183.64	57.57	0.31	0.00	9.15
RIL-115	75.2	74.2	1.33	300.29	2.35	4.39	15.16	3.83	12.05	70.45	187.11	55.03	0.29	0.37	40.33
RIL-116	77.6	75.8	1.67	861.47	2.50	3.66	14.73	3.49	11.06	71.40	171.41	53.34	0.31	0.43	10.24
RIL-118	76.8	75.3	1.33	419.05	2.57	4.72	15.03	3.87	11.57	70.31	185.77	54.19	0.29	0.00	14.83
RIL-122	76.2	75.4	0.67	241.78	2.37	3.71	14.53	3.68	11.37	71.23	183.11	54.19	0.30	0.00	11.35
RIL-123	75.3	74.2	1.33	242.35	2.18	5.11	15.04	4.13	11.30	70.02	184.82	58.42	0.32	0.37	16.31
DKC 66-80	75.3	74.3	1.33	505.96	2.67	7.13	15.18	3.49	10.12	71.91	193.20	62.65	0.33	0.37	7.84
RIL-127	77.4	76.2	0.67	239.96	2.14	4.16	15.37	4.01	11.21	70.17	184.61	53.34	0.29	0.00	12.37
RIL-132	75.3	74.2	1.33	216.44	2.32	5.49	15.15	4.11	11.33	70.43	185.42	56.73	0.31	0.00	13.01
RIL-133	74.8	74.4	0.67	1129.11	3.01	4.59	15.18	3.63	10.16	71.75	188.11	55.03	0.30	0.00	4.06

Appendix 2. (continued).

RIL	Days to Silk	Days to Anthesis	ASI	Aflatoxin	Log Aflatoxin	GY	Grain Moist	Oil	Protein	Starch	Plant height	Ear Height	EPR	Stalk Lodge	Nodded Ear
	d	d	d	ppb		tn/ha	%	%	%	%	cm	cm		%	%
RIL-134	76.7	74.5	2.00	500.95	2.58	4.38	14.45	4.13	11.26	70.20	193.36	61.81	0.32	0.97	8.10
RIL-135	76.7	74.8	2.00	319.08	2.44	3.69	14.86	3.96	10.99	70.74	191.24	58.42	0.31	0.00	5.64
RIL-137	78.0	75.7	2.00	688.08	2.84	5.66	15.48	4.04	10.90	70.03	205.44	69.43	0.34	0.73	4.19
RIL-138	76.8	74.8	2.00	689.90	2.60	4.86	15.04	3.78	11.49	70.74	184.32	59.27	0.32	0.40	11.14
RIL-140	76.0	75.4	0.67	155.37	2.12	3.11	14.79	4.02	10.68	71.38	184.46	56.73	0.31	0.00	16.08
RIL-141	76.1	74.4	2.00	128.52	2.09	4.32	14.99	3.81	11.40	70.91	187.25	56.73	0.30	0.40	22.57
RIL-144	77.2	75.0	2.00	301.78	2.41	5.08	15.72	3.98	12.02	70.02	205.84	69.43	0.34	0.87	9.87
RIL-145	75.9	74.2	2.00	458.47	2.51	6.03	15.38	3.79	11.54	70.35	199.94	64.35	0.32	1.17	55.00
RIL-147	75.9	74.6	1.33	440.04	2.59	5.10	14.76	4.01	11.44	70.33	208.16	60.96	0.29	1.23	9.36
RIL-150	76.1	74.3	1.67	117.00	2.01	4.43	15.51	3.63	10.85	71.13	177.70	56.74	0.32	1.17	32.64
RIL-151	75.5	74.8	0.67	196.12	2.25	4.72	15.53	4.02	11.02	70.45	187.42	54.19	0.29	0.90	13.76
RIL-153	77.3	75.3	2.00	430.87	2.44	4.96	15.38	3.92	11.26	70.62	196.40	60.96	0.31	0.00	14.80
RIL-154	76.0	74.8	1.33	224.79	2.33	4.91	15.29	3.78	10.25	71.56	188.62	59.27	0.31	0.00	3.81
RIL-156	74.7	74.4	0.67	395.00	2.55	3.79	15.00	3.73	10.92	71.17	189.58	60.11	0.32	0.00	11.42
RIL-157	76.6	74.7	2.00	343.77	2.53	3.71	15.26	3.90	10.90	70.73	192.88	60.96	0.32	0.00	18.39
RIL-158	76.8	74.8	2.00	443.58	2.67	4.45	15.57	4.08	11.37	70.33	190.83	58.42	0.31	0.83	9.42
RIL-162	76.6	74.4	2.00	191.94	2.28	4.21	15.26	3.74	11.50	71.03	178.63	58.42	0.33	0.00	9.47
RIL-165	76.1	74.4	2.00	304.98	2.42	5.31	15.12	3.62	10.39	71.73	193.39	60.11	0.31	0.00	14.56
RIL-170	75.8	74.1	2.00	1013.23	2.86	4.28	14.40	4.13	11.17	70.04	170.33	53.34	0.31	0.00	7.22
RIL-172	76.0	75.4	0.67	395.29	2.59	4.77	15.15	3.73	10.91	71.30	197.46	63.50	0.32	0.00	2.73
RIL-173	74.7	74.9	0.00	158.67	2.18	4.69	14.97	3.90	10.96	70.75	193.17	54.19	0.28	0.00	4.30
RIL-174	78.7	76.0	2.33	403.97	2.51	5.38	14.33	3.84	10.41	71.45	195.59	60.11	0.31	0.40	14.09
RIL-175	77.4	75.4	2.00	356.01	2.48	4.17	14.37	3.90	10.94	70.81	183.10	57.57	0.31	0.00	8.18
RIL-177	76.8	75.9	0.67	717.76	2.69	4.84	14.64	3.82	11.08	70.66	196.57	64.35	0.33	0.40	9.51
RIL-178	76.0	75.3	0.67	1250.55	2.89	3.63	14.38	3.74	11.98	70.52	186.56	60.96	0.33	0.00	26.89
RIL-180	75.3	74.3	1.33	222.10	2.31	5.04	15.06	4.27	11.86	69.84	182.62	58.42	0.32	0.00	6.32
RIL-184	76.7	75.3	1.33	638.28	2.68	4.07	14.26	4.11	11.75	70.03	195.69	69.43	0.36	0.00	6.16
RIL-185	76.1	74.1	2.00	184.20	2.22	5.04	15.14	3.83	10.56	70.97	187.79	55.88	0.30	0.37	15.63

Appendix 2. (continued).

RIL	Days to Silk	Days to Anthesis	ASI	Aflatoxin	Log Aflatoxin	GY	Grain Moist	Oil	Protein	Starch	Plant height	Ear Height	EPR	Stalk Lodge	Nodded Ear
	d	d	d	ppb		tn/ha	%	%	%	%	cm	cm		%	%
RIL-186	78.0	75.6	2.00	232.80	2.21	4.01	14.57	3.40	11.22	71.61	184.85	59.27	0.32	0.00	7.81
RIL-187	77.3	75.7	1.33	322.47	2.50	4.26	15.00	3.51	11.00	71.76	203.17	66.04	0.32	0.00	10.58
RIL-190	76.5	75.2	1.33	180.06	2.19	5.57	15.49	4.18	11.23	70.18	192.78	60.96	0.32	0.37	12.70
RIL-192	77.2	75.2	2.00	445.62	2.64	4.80	15.25	3.57	11.67	71.15	195.47	65.19	0.33	0.00	13.66
RIL-195	75.3	74.1	1.33	488.94	2.65	5.10	15.53	4.08	11.36	70.29	187.75	59.27	0.32	0.40	23.27
RIL-198	77.2	75.1	2.00	559.60	2.44	5.31	15.18	3.86	11.41	70.62	188.66	66.04	0.35	0.00	5.74
RIL-199	77.9	75.7	2.00	199.31	2.27	5.66	15.42	3.64	9.96	71.72	184.63	57.57	0.31	0.00	9.79
RIL-203	76.4	74.6	2.00	437.35	2.57	4.12	15.17	3.34	11.03	71.82	190.29	59.27	0.31	0.00	21.23
RIL-205	76.0	74.8	1.33	237.09	2.20	4.48	14.83	3.66	11.33	70.73	189.48	52.49	0.28	0.87	11.36
RIL-207	75.5	74.3	1.33	527.51	2.65	4.15	14.70	3.77	11.03	71.14	167.92	50.80	0.30	0.00	11.93
RIL-208	76.0	74.8	1.33	342.24	2.49	4.74	14.97	3.93	11.27	70.85	190.52	54.19	0.29	0.00	10.25
RIL-212	76.1	74.4	2.00	568.14	2.63	5.27	15.03	3.92	10.68	71.02	182.15	60.11	0.33	0.00	5.25
RIL-213	76.6	74.7	2.00	594.07	2.72	4.84	14.88	3.89	10.67	70.93	185.04	57.57	0.31	0.00	8.21
RIL-216	75.2	74.7	0.67	788.74	2.68	5.08	15.14	3.74	10.90	71.26	175.46	52.49	0.30	0.80	7.79
RIL-217	79.3	77.4	1.00	885.62	2.81	3.38	14.84	3.73	10.78	71.11	183.76	59.27	0.32	0.00	27.23
RIL-220	75.4	74.2	1.33	235.42	2.39	5.40	15.33	3.96	10.11	70.57	187.29	60.11	0.32	0.00	11.59
RIL-221	76.6	75.2	1.33	430.13	2.59	3.74	14.46	3.85	10.38	71.52	180.26	54.19	0.30	0.57	21.39
RIL-222	76.6	74.8	2.00	592.10	2.70	5.90	14.78	3.77	11.51	70.45	190.61	240.45	1.25	2.20	6.94
RIL-225	77.4	74.9	2.67	694.67	2.72	3.66	15.35	3.81	10.68	71.33	181.92	55.03	0.30	0.00	8.14
RIL-226	76.0	74.3	2.00	447.08	2.55	4.58	14.92	3.80	11.78	70.29	188.79	59.27	0.31	0.80	12.87
RIL-229	77.8	76.2	1.33	607.33	2.61	5.13	15.46	3.99	11.29	70.24	200.10	59.27	0.30	1.20	0.99
RIL-232	76.7	74.7	2.00	805.25	2.79	4.10	14.79	3.97	12.24	69.69	185.53	57.57	0.31	9.53	13.40
RIL-233	75.3	74.2	1.33	368.76	2.55	5.17	15.12	3.89	11.22	70.69	182.05	55.88	0.31	0.53	12.98
RIL-237	74.1	74.4	0.00	200.04	2.29	4.75	15.39	3.86	10.79	70.40	184.58	55.03	0.30	0.00	11.80
RIL-239	76.1	74.3	2.00	386.28	2.60	5.33	15.04	3.76	10.42	71.58	188.14	55.88	0.30	0.37	1.81
RIL-241	76.1	74.3	2.00	609.00	2.73	5.22	15.28	4.27	11.03	70.12	203.70	56.73	0.28	0.37	5.93
RIL-243	76.6	75.5	0.67	155.05	2.17	4.97	14.70	3.84	10.16	71.48	185.77	59.27	0.32	0.00	6.04
RIL-244	75.3	74.1	1.33	723.24	2.71	6.11	15.00	4.25	10.55	70.45	180.61	56.73	0.32	1.13	10.02

Appendix 2. (continued).

RIL	Days to Silk	Days to Anthesis	ASI	Aflatoxin	Log Aflatoxin	GY	Grain Moist	Oil	Protein	Starch	Plant height	Ear Height	EPR	Stalk Lodge	Nodded Ear
	d	d	d	ppb		tn/ha	%	%	%	%	cm	cm		%	%
RIL-247	76.8	74.8	2.00	380.03	2.55	4.54	14.35	4.02	12.24	69.67	189.19	60.96	0.32	0.37	22.86
RIL-250	76.8	74.8	2.00	168.95	2.12	4.77	15.00	3.86	11.49	70.51	200.91	62.65	0.31	0.40	5.34
RIL-251	76.6	75.1	1.33	1226.79	3.05	4.63	14.85	3.63	10.32	71.58	187.29	61.81	0.33	0.43	20.23
RIL-255	78.9	76.8	1.33	673.60	2.75	5.06	15.52	3.84	10.44	71.03	182.03	54.19	0.30	0.00	18.82
RIL-256	78.9	76.2	2.33	344.86	2.54	4.78	14.88	3.69	11.20	71.29	181.16	53.34	0.30	0.00	9.84
RIL-259	75.4	74.3	1.33	221.36	2.29	4.97	14.96	3.91	12.41	70.14	192.17	57.57	0.30	1.50	11.51
RIL-260	76.0	74.9	1.33	460.26	2.54	4.40	15.28	3.68	11.82	70.48	197.28	57.57	0.29	0.00	14.76
RIL-261	76.1	74.3	2.00	971.80	2.90	4.26	13.91	3.83	11.49	70.57	177.26	57.57	0.32	0.43	17.40
RIL-262	77.1	75.7	1.33	956.68	2.62	4.40	15.16	3.59	11.60	70.76	186.86	57.57	0.31	0.00	28.12
RIL-266	77.1	75.1	1.67	309.00	2.47	5.08	14.83	3.75	10.66	71.27	195.23	61.82	0.31	1.72	1.72
RIL-268	80.1	76.7	2.67	582.76	2.67	4.47	15.11	3.68	10.70	71.32	196.72	65.19	0.34	0.00	15.81
RIL-269	77.4	75.4	2.00	753.18	2.71	5.14	15.29	3.35	11.33	71.56	202.38	73.66	0.36	0.00	10.38
RIL-272	76.5	75.1	1.33	241.96	2.39	5.72	15.52	3.70	11.17	71.04	186.17	63.50	0.34	0.47	9.25
RIL-274	78.2	75.9	2.00	270.89	2.40	4.69	14.90	3.39	10.80	71.59	202.46	66.89	0.33	0.00	11.67
RIL-275	76.0	74.3	2.00	290.45	2.44	4.64	14.73	4.10	11.51	70.72	183.04	54.19	0.30	0.00	8.04
RIL-276	76.1	74.3	2.00	314.32	2.47	5.04	14.97	4.42	11.44	69.97	188.94	64.35	0.34	0.00	3.21
RIL-277	74.0	75.8	1.33	153.61	2.03	3.41	15.06	3.54	11.47	70.85	184.07	61.81	0.34	0.00	10.99
RIL-279	75.5	74.3	1.33	474.67	2.65	4.26	14.77	4.20	11.96	69.89	183.59	64.35	0.35	0.43	10.62
RIL-280	76.0	74.8	1.33	1132.19	2.81	4.97	14.83	3.62	9.90	71.63	184.63	59.27	0.32	0.47	18.28
RIL-281	76.2	74.8	1.33	420.22	2.57	5.28	13.96	3.64	10.31	71.37	195.88	60.96	0.31	1.27	10.54
RIL-282	76.1	74.3	2.00	404.18	2.58	5.39	15.64	3.96	11.83	70.01	194.14	61.81	0.32	0.37	8.97
RIL-283	76.1	74.4	2.00	256.10	2.32	5.49	15.40	4.18	12.15	69.39	199.14	66.89	0.34	1.13	5.33
RIL-285	75.3	74.3	1.33	321.09	2.49	5.37	14.13	4.25	11.68	69.52	191.51	64.35	0.34	0.37	26.73
RIL-286	76.8	75.4	1.33	478.47	2.69	4.22	15.08	3.97	11.85	70.59	192.93	61.81	0.32	0.00	24.07
CML161/LH195	75.9	75.1	0.67	147.37	2.08	5.28	15.40	4.11	10.53	70.64	198.50	61.81	0.31	1.70	5.19
B73 o2/LH195	79.0	77.2	1.00	617.79	2.71	1.77	14.30	3.53	10.70	71.83	164.90	56.73	0.35	0.00	19.20
P31B13	76.7	75.3	1.33	558.89	2.74	6.51	15.75	3.73	9.44	72.03	172.04	60.11	0.35	0.73	22.58
B73 o2/LH195	81.0	78.6	1.00	1470.61	2.98	1.76	14.59	3.48	11.12	71.72	168.44	49.11	0.29	0.00	13.66

Appendix 3. Phenotypic data for aflatoxin trial at Corpus Christi, TX during 2008.

RIL #	Days to Silk	Aflatoxin	Log Aflatoxin	AntiLog Aflatoxin	Grain Yield	Oil	Protein	Starch	Stay Green	Grain Texture	Aflatoxin Rating
	days	ppb			tn/ha	%	%	1-5	1-5	1-5	1-5
RIL-1	65.37	111.00	1.92	83.18	1.09	3.48	12.40	70.10	3.25	4.26	2.97
RIL-2	66.08	144.33	1.86	72.44	0.93	3.01	12.88	70.79	3.75	2.52	2.69
RIL-3	63.22	136.67	2.11	128.82	1.67	2.94	11.54	71.96	3.75	2.68	2.33
RIL-7	64.59	49.33	1.64	43.65	1.89	3.25	11.82	71.08	3.25	3.27	1.94
RIL-9	62.73	34.33	1.39	24.55	1.37	2.82	12.72	71.14	4.50	2.75	2.64
RIL-10	63.44	58.67	1.42	26.30	1.53	2.43	12.69	72.14	3.50	2.21	3.00
RIL-11	64.40	73.00	1.72	52.48	0.78	3.05	8.86	71.60	4.25	2.90	1.89
RIL-21	63.26	21.67	1.32	20.89	1.44	2.73	12.55	71.93	4.25	2.55	2.17
RIL-23	63.95	43.33	1.56	36.31	1.31	2.76	12.65	71.57	3.50	2.72	2.16
RIL-28	64.58	173.33	2.21	162.18	1.27	2.50	12.39	71.62	3.50	2.18	2.63
RIL-31	64.25	7.00	0.71	5.13	1.15	2.03	13.63	71.75	4.50	2.50	2.27
RIL-37	62.39	41.67	1.61	40.74	1.57	2.60	12.66	71.96	4.00	3.05	2.00
RIL-39	61.42	143.00	1.84	69.18	1.35	2.53	12.17	71.91	4.25	3.15	1.82
RIL-41	65.75	215.00	2.27	186.21	0.98	2.98	11.82	71.62	2.75	2.62	2.49
RIL-42	62.66	326.67	2.20	158.49	1.58	3.06	12.74	70.89	3.25	2.98	1.83
RIL-44	62.68	22.33	1.25	17.78	1.52	2.43	12.87	71.70	4.00	2.50	2.07
RIL-45	63.96	75.67	1.82	66.07	1.58	2.71	214.35	71.72	3.50	2.47	2.35
RIL-54	64.02	96.67	1.79	61.66	0.62	2.84	13.13	71.26	3.25	3.68	1.56
RIL-56	66.98	136.67	2.12	131.83	0.92	3.18	11.76	71.35	2.75	3.51	2.18
RIL-57	66.58	109.00	1.84	69.18	0.97	2.74	12.49	71.51	3.00	3.16	1.66
RIL-59	65.19	29.33	1.30	19.95	1.65	3.30	12.55	70.78	3.25	2.32	2.40
RIL-61	62.96	97.33	1.90	79.43	1.33	2.97	11.23	72.05	3.00	3.17	2.48
RIL-63	65.25	230.00	2.35	223.87	0.80	2.52	12.31	72.73	3.75	3.29	2.12
RIL-64	64.06	96.67	1.98	95.50	1.13	3.22	11.26	71.74	4.00	2.87	2.30
RIL-67	66.24	130.33	1.88	75.86	0.66	2.37	10.32	71.69	3.75	3.59	2.39
RIL-68	65.67	139.00	2.14	138.04	1.35	2.61	13.03	71.70	3.50	3.74	2.92
RIL-72	64.04	47.00	1.37	23.44	1.46	2.89	12.47	71.10	3.75	3.39	2.54
RIL-75	64.24	66.67	1.78	60.26	1.21	3.07	12.90	70.78	3.50	2.18	2.51
RIL-76	64.72	73.33	1.82	66.07	1.28	2.96	11.44	72.21	3.50	3.55	2.24
RIL-80	66.04	184.67	2.19	154.88	0.82	2.83	14.91	71.96	2.75	2.64	2.46
RIL-82	62.93	30.00	1.33	21.38	1.66	2.41	13.30	71.72	4.25	2.81	1.93
RIL-85	64.30	16.67	1.02	10.47	1.19	3.19	11.46	71.48	2.75	2.83	2.50
RIL-88	63.35	56.67	1.68	47.86	1.55	3.54	13.02	69.98	3.75	2.73	2.30
BH9012	59.05	30.67	1.16	14.45	2.79	2.83	11.49	72.05	3.00	2.25	2.18
RIL-91	65.28	18.33	1.22	16.60	1.27	3.23	11.78	71.86	3.00	2.65	2.52
RIL-92	63.93	26.00	1.33	21.38	1.21	3.08	11.90	71.52	4.50	3.62	1.64
RIL-97	64.00	81.00	1.52	33.11	1.34	2.91	12.27	71.54	3.25	2.77	2.54
RIL-99	64.61	151.67	2.02	104.71	1.32	2.67	11.22	72.36	3.00	2.74	2.35
RIL-101	64.01	46.00	1.51	32.36	1.47	3.05	13.05	70.56	3.75	2.65	2.56
RIL-102	64.69	10.67	0.87	7.41	1.04	2.70	12.36	71.78	3.50	2.76	1.98
RIL-105	59.66	137.67	2.01	102.33	2.08	2.69	11.28	71.90	4.50	2.84	2.50
RIL-106	61.60	33.67	1.45	28.18	2.35	2.37	13.75	71.19	3.75	2.36	2.46
RIL-109	65.80	384.00	1.96	91.20	0.52	.	.	.	4.50	2.22	2.75
RIL-111	64.37	51.67	1.63	42.66	1.05	2.79	12.79	71.34	4.75	3.44	2.14

Appendix 3. (continued).

RIL #	Days to Silk	Aflatoxin	Log Aflatoxin	AntiLog Aflatoxin	Grain Yield	Oil	Protein	Starch	Stay Green	Grain Texture	Aflatoxin Rating
	days	ppb			tn/ha	%	%	1-5	1-5	1-5	1-5
RIL-112	64.62	440.67	2.38	239.88	1.16	3.05	11.21	71.93	3.00	3.22	1.85
RIL-113	62.31	141.67	2.05	112.20	1.34	3.50	11.60	71.00	3.00	2.99	2.98
RIL-114	64.99	26.00	1.14	13.80	0.95	2.80	13.41	70.48	4.50	3.02	1.81
RIL-115	64.63	58.33	1.74	54.95	1.04	3.07	13.92	70.06	3.50	2.81	2.53
RIL-116	64.37	31.33	1.45	28.18	1.22	2.69	13.03	71.69	4.25	3.20	2.13
RIL-118	65.69	38.00	1.56	36.31	1.01	2.55	13.34	72.01	4.75	2.87	2.38
RIL-122	64.36	48.33	1.42	26.30	1.27	3.30	11.70	71.18	3.50	2.86	2.48
RIL-123	61.08	28.33	1.47	29.51	1.60	3.07	12.16	71.47	3.75	2.31	2.08
DKC 66-80	63.05	116.33	1.97	93.33	2.22	3.08	10.84	72.12	2.25	1.61	2.65
RIL-127	64.35	66.67	1.70	50.12	1.04	3.07	12.04	71.37	3.75	2.51	2.47
RIL-132	59.95	88.33	1.80	63.10	1.62	2.56	12.94	71.41	4.50	2.58	2.20
RIL-133	64.72	37.33	1.34	21.88	1.08	2.77	12.13	71.33	4.25	3.31	1.57
RIL-134	64.08	87.67	1.67	46.77	1.18	3.33	11.72	71.30	3.25	2.87	2.61
RIL-135	64.98	264.00	2.21	162.18	1.15	3.12	12.68	70.48	3.50	2.64	2.00
RIL-137	64.04	57.67	1.65	44.67	1.32	2.86	12.19	71.93	3.25	3.01	2.14
RIL-138	64.36	46.67	1.55	35.48	1.60	2.54	12.32	72.02	4.00	3.03	2.31
RIL-140	65.01	667.67	2.44	275.42	0.36	2.67	9.86	71.75	4.25	2.32	2.61
RIL-141	63.02	166.33	1.86	72.44	1.13	2.47	13.12	71.62	5.00	2.31	2.02
RIL-144	63.03	57.00	1.70	50.12	1.94	2.92	13.01	71.06	3.00	2.55	2.21
RIL-145	62.71	72.67	1.77	58.88	1.62	2.52	13.05	71.27	3.75	2.37	2.49
RIL-147	63.98	53.67	1.65	44.67	2.07	3.28	12.03	70.97	3.00	2.80	2.52
RIL-150	62.05	630.00	2.75	562.34	1.49	2.61	12.47	71.24	4.50	2.24	2.18
RIL-151	61.92	70.67	1.36	22.91	1.55	2.50	12.15	72.10	3.75	2.96	2.48
RIL-153	64.34	112.00	1.95	89.13	1.48	2.82	12.23	71.62	3.50	2.49	2.33
RIL-154	64.04	48.67	1.60	39.81	1.36	2.59	11.71	72.32	3.50	3.04	2.52
RIL-156	64.68	96.00	1.88	75.86	1.09	2.46	12.51	72.15	3.75	2.17	2.22
RIL-157	64.01	42.00	1.56	36.31	0.92	2.64	12.44	71.98	3.75	2.33	2.34
RIL-158	66.68	27.67	1.35	22.39	0.38	.	.	.	3.75	3.03	2.62
RIL-162	65.01	236.00	2.24	173.78	1.17	2.66	12.79	71.66	3.00	3.38	2.27
RIL-165	63.68	43.67	1.58	38.02	1.47	2.86	11.84	71.85	3.75	3.31	2.02
RIL-170	64.96	50.00	1.73	53.70	0.81	3.17	13.20	70.13	4.50	2.78	2.48
RIL-172	64.11	69.33	1.77	58.88	1.17	2.82	12.22	71.76	3.25	2.80	2.37
RIL-173	65.08	99.33	1.92	83.18	1.10	2.71	12.69	71.48	3.25	2.83	1.92
RIL-174	64.38	64.33	1.74	54.95	1.75	2.86	11.99	71.75	3.75	2.57	2.36
RIL-175	65.72	32.00	1.11	12.88	1.01	3.20	12.05	71.05	3.25	2.21	1.97
RIL-177	64.02	81.67	1.74	54.95	1.13	2.42	12.76	71.98	3.75	2.15	1.97
RIL-178	66.88	245.00	2.29	194.98	0.19	.	.	.	3.25	2.75	2.25
RIL-180	63.97	144.00	2.04	109.65	1.28	3.38	12.34	71.24	3.25	3.33	2.19
RIL-184	66.24	195.00	2.22	165.96	0.71	2.81	9.89	71.33	3.50	2.17	1.80
RIL-185	63.09	153.33	2.17	147.91	1.66	2.93	11.73	71.70	3.50	2.49	2.15
RIL-186	65.23	125.00	1.93	85.11	1.09	3.14	11.75	71.62	2.75	3.08	2.68
RIL-187	68.32	22.67	1.13	13.49	0.59	3.50	14.80	71.10	3.00	3.20	2.10
RIL-190	64.01	40.33	1.55	35.48	1.82	3.39	11.78	71.15	3.00	2.98	1.52
RIL-192	66.67	186.00	2.09	123.03	1.35	2.52	13.23	71.46	3.25	2.81	1.81

Appendix 3. (continued).

RIL #	Days to Silk	Aflatoxin	Log Aflatoxin	AntiLog Aflatoxin	Grain Yield	Oil	Protein	Starch	Stay Green	Grain Texture	Aflatoxin Rating
	days	ppb			tn/ha	%	%	1-5	1-5	1-5	1-5
RIL-195	63.65	97.67	1.93	85.11	1.05	3.08	12.45	71.08	4.25	2.16	2.38
RIL-198	63.66	32.00	1.38	23.99	1.29	2.74	12.97	71.55	3.75	2.49	2.54
RIL-199	63.83	56.00	1.62	41.69	2.29	3.30	11.05	71.54	2.75	3.28	2.18
RIL-203	65.39	102.67	2.05	112.20	1.21	2.94	12.27	71.39	2.75	2.85	1.51
RIL-205	63.70	40.33	1.32	20.89	1.80	2.92	11.65	71.71	4.25	2.29	2.70
RIL-207	62.73	23.33	0.96	9.12	1.35	2.76	12.62	71.50	4.00	3.11	2.16
RIL-208	63.97	205.67	2.19	154.88	1.12	3.24	12.01	71.18	3.25	3.06	2.15
RIL-212	66.08	73.33	1.63	42.66	1.27	2.61	12.93	71.37	3.50	3.00	2.37
RIL-213	64.09	31.67	1.13	13.49	1.47	2.66	12.39	71.96	4.00	2.15	1.93
RIL-216	60.70	26.00	1.35	22.39	1.71	2.77	12.07	72.17	3.50	3.18	2.35
RIL-217	66.32	762.67	2.41	257.04	0.44	3.08	9.66	70.40	3.00	2.72	2.51
RIL-220	60.60	57.67	1.71	51.29	1.84	2.80	11.81	72.04	3.50	3.08	1.83
RIL-221	65.10	74.33	1.34	21.88	0.53	3.32	12.60	70.59	4.50	2.31	2.56
RIL-222	63.06	83.00	1.87	74.13	1.55	2.53	12.77	71.74	3.50	2.07	2.44
RIL-225	66.33	80.00	1.40	25.12	0.84	2.78	13.51	70.98	4.50	3.13	2.44
RIL-226	64.59	121.67	2.01	102.33	1.11	2.58	12.23	72.13	3.75	3.23	2.29
RIL-229	65.01	33.00	1.50	31.62	1.62	3.09	12.21	70.96	3.75	2.91	2.13
RIL-232	64.66	89.00	1.78	60.26	1.02	2.58	13.44	71.45	3.75	1.63	2.33
RIL-233	63.97	83.33	1.94	87.10	1.84	3.27	12.10	70.99	3.00	3.19	2.31
RIL-237	63.96	62.00	1.75	56.23	1.58	3.04	13.03	70.76	2.75	2.67	2.65
RIL-239	61.26	70.33	1.62	41.69	1.58	3.22	11.64	71.39	3.75	3.29	1.83
RIL-241	63.01	43.33	1.02	10.47	1.50	3.27	12.40	70.71	4.00	2.90	2.26
RIL-243	64.13	41.33	1.59	38.90	1.38	2.52	12.30	72.11	3.50	2.32	2.21
RIL-244	63.96	85.33	1.80	63.10	1.41	2.99	12.45	71.43	3.75	1.85	1.86
RIL-247	63.99	171.67	2.15	141.25	1.55	3.47	12.47	70.31	3.25	2.85	2.13
RIL-250	64.04	33.00	1.52	33.11	1.48	3.59	11.84	70.76	3.25	3.02	2.97
RIL-251	63.65	48.67	1.70	50.12	0.91	2.56	12.41	72.06	3.75	3.18	2.34
RIL-255	64.34	174.33	2.06	114.82	1.59	3.05	12.45	70.97	2.50	3.66	2.33
RIL-256	64.29	87.67	1.71	51.29	1.50	3.04	12.44	71.01	3.25	3.54	1.79
RIL-259	63.98	115.33	1.92	83.18	1.43	3.54	12.76	70.26	4.00	3.27	2.25
RIL-260	64.35	132.00	1.77	58.88	1.71	2.61	12.57	71.67	3.50	3.81	2.19
RIL-261	62.84	183.67	2.07	117.49	1.23	2.76	12.83	71.19	3.75	2.88	2.88
RIL-262	65.62	139.33	1.96	91.20	0.91	3.13	12.74	70.69	2.50	3.57	2.61
RIL-266	63.75	259.33	2.18	151.36	1.35	3.55	13.02	69.79	3.25	2.03	1.90
RIL-268	67.27	172.67	2.18	151.36	0.92	3.20	13.25	70.41	3.25	2.64	2.15
RIL-269	65.69	144.33	1.85	70.79	1.37	2.83	13.05	70.84	3.25	2.83	1.67
RIL-272	65.70	131.00	2.12	131.83	1.60	3.18	12.46	70.74	3.50	2.87	2.17
RIL-274	65.69	137.67	1.93	85.11	0.88	2.55	12.55	71.57	3.75	2.15	1.78
RIL-275	65.98	196.00	2.09	123.03	1.19	3.56	12.33	70.85	3.50	3.42	2.52
RIL-276	65.89	59.67	1.52	33.11	0.62	2.93	209.33	71.75	4.50	2.44	1.76
RIL-277	66.10	410.00	2.41	257.04	0.52	.	.	.	2.75	2.89	2.65
RIL-279	65.38	73.33	1.79	61.66	0.89	3.23	13.01	70.89	3.50	3.16	2.37
RIL-280	64.92	84.33	1.72	52.48	1.16	2.48	12.06	72.32	3.75	1.50	2.00
RIL-281	64.78	20.67	1.16	14.45	0.78	2.27	9.11	72.24	3.50	1.92	2.45

Appendix 3. (continued).

RIL #	Days to Silk	Aflatoxin	Log Aflatoxin	AntiLog Aflatoxin	Grain Yield	Oil	Protein	Starch	Stay Green	Grain Texture	Aflatoxin Rating
	days	ppb			tn/ha	%	%	1-5	1-5	1-5	1-5
RIL-282	64.29	240.33	2.10	125.89	1.27	3.10	13.22	70.31	3.50	2.29	1.69
RIL-283	64.01	47.67	1.65	44.67	1.55	2.89	13.60	70.58	3.00	2.43	2.19
RIL-285	63.16	29.00	1.44	27.54	1.34	3.12	13.56	70.08	3.50	2.83	1.62
RIL-286	63.96	96.67	1.88	75.86	1.03	2.93	12.66	71.05	3.50	2.98	2.57
CML161/LH195	63.98	76.00	1.75	56.23	2.04	3.36	11.21	71.50	3.50	3.22	2.16
B73 o2/LH195	65.78	191.33	2.06	114.82	0.21	.	.	.	4.00	2.53	2.50
P31B13	59.76	173.00	2.16	144.54	2.92	2.77	10.39	73.01	3.25	2.28	1.85
B73 o2/LH195	66.42	181.33	1.07	11.75	0.13	.	.	.	4.50	2.79	2.17

Appendix 4. Phenotypic data for aflatoxin trials at College Station, TX during 2009.

RIL	Starch	Protein	Oil	LogAf	AntiLog AF	AF	Test Weight	Moist	Log GY	Grain Yield	Plant Pop.	EPR	Plant Height	Ear Height	ASI	Days to Silk	Days to Anthesis
RIL-2	71.55	9.96	3.46	2.08	120.23	150.47	71.29	12.98	0.73	5.44	75035.80	0.39	233.85	90.84	0.72	82.29	81.72
RIL-3	72.14	9.99	3.26	2.06	114.82	190.72	68.65	12.98	0.72	5.24	73055.26	0.40	226.64	91.45	0.61	82.50	81.41
RIL-9	71.41	10.81	3.50	2.06	114.82	189.69	69.50	12.98	0.69	5.00	66878.96	0.42	224.43	95.08	0.62	81.36	80.50
RIL-10	71.17	10.70	3.39	2.03	107.15	207.25	68.99	12.97	0.74	5.53	66259.30	0.43	243.11	104.91	0.61	82.27	81.27
RIL-11	72.22	9.55	3.43	2.07	117.49	184.34	70.72	12.97	0.74	5.65	71604.48	0.37	246.13	90.84	0.61	82.29	81.26
RIL-21	71.84	10.80	3.03	2.09	123.03	145.05	68.72	12.98	0.72	5.30	68410.05	0.39	244.04	94.45	0.74	81.73	81.12
RIL-23	71.47	11.03	3.22	2.07	117.49	159.14	68.75	12.99	0.74	5.49	70835.16	0.41	239.74	98.37	0.63	82.30	81.41
RIL-28	71.57	10.36	3.28	2.07	117.49	114.53	71.29	12.96	0.77	5.91	68631.99	0.40	234.86	94.31	0.71	81.49	80.97
RIL-31	72.15	10.37	3.18	2.02	104.71	210.59	71.83	12.96	0.76	5.80	71989.46	0.40	243.10	97.15	0.69	82.08	81.28
RIL-37	71.78	10.46	3.33	2.08	120.23	165.66	71.69	12.96	0.73	5.43	65836.89	0.40	235.45	93.29	0.61	81.54	80.50
RIL-39	72.17	10.03	3.33	2.04	109.65	212.06	70.68	12.99	0.75	5.68	70694.32	0.41	237.86	98.16	0.79	81.69	81.27
RIL-41	72.47	9.68	3.16	2.07	117.49	196.41	70.24	12.99	0.73	5.37	66864.04	0.40	235.42	94.48	0.81	82.36	81.72
RIL-42	71.19	10.49	3.80	2.04	109.65	208.51	70.99	12.97	0.74	5.54	69932.39	0.40	243.73	97.15	0.63	82.37	81.25
RIL-44	71.30	10.65	3.38	2.06	114.82	178.73	68.66	12.97	0.73	5.43	66924.11	0.40	245.29	96.73	0.74	82.27	81.58
RIL-45	71.90	9.86	3.37	2.03	107.15	196.14	68.78	12.99	0.75	5.78	70588.95	0.41	229.54	96.05	0.63	82.48	81.42
RIL-56	72.10	9.96	3.46	2.05	112.20	202.94	70.76	12.98	0.70	5.14	65766.25	0.40	241.72	96.57	0.79	82.72	82.02
RIL-57	72.60	9.65	3.28	2.06	114.82	191.52	70.71	12.98	0.70	5.19	65091.59	0.41	244.10	99.58	0.88	83.25	82.65
RIL-59	70.66	11.11	3.68	2.05	112.20	189.90	71.61	12.97	0.77	5.86	73614.18	0.41	246.25	100.43	0.61	81.90	80.97
RIL-61	72.36	9.37	3.37	2.05	112.20	195.74	71.53	12.98	0.77	5.86	66402.70	0.40	233.83	93.41	0.63	81.97	80.95
RIL-63	71.43	10.47	3.45	2.11	128.82	168.79	69.62	12.99	0.73	5.49	62073.82	0.40	244.70	96.52	0.77	82.34	81.58
RIL-64	71.56	10.13	3.65	2.05	112.20	206.51	70.88	12.99	0.72	5.30	66703.13	0.38	241.02	90.59	0.67	81.74	81.10
RIL-67	72.31	9.76	3.29	2.05	112.20	210.36	69.02	13.00	0.71	5.21	67898.40	0.42	246.55	102.87	0.70	83.45	82.48
RIL-68	71.85	10.81	3.20	2.06	114.82	178.97	69.99	12.98	0.74	5.45	73168.84	0.41	235.51	95.55	0.71	82.44	81.73
RIL-72	72.59	10.18	3.07	2.06	114.82	202.61	70.98	12.99	0.66	4.70	65982.30	0.40	233.98	93.04	0.78	82.69	81.89
RIL-75	71.48	10.81	3.32	2.07	117.49	159.42	72.27	12.98	0.74	5.55	68354.06	0.37	248.19	91.43	0.60	81.81	80.79
RIL-76	71.46	10.57	3.47	2.04	109.65	191.72	70.77	12.97	0.72	5.38	70530.46	0.37	238.06	87.77	0.61	81.51	80.66
RIL-80	71.62	10.03	3.56	2.09	123.03	145.43	68.57	12.99	0.71	5.18	66394.88	0.39	240.60	93.46	0.65	82.07	81.27
RIL-82	72.09	10.14	3.25	2.05	112.20	200.00	72.46	12.97	0.81	6.56	66610.05	0.39	249.59	97.73	0.73	81.57	80.96
RIL-85	72.04	9.80	3.41	2.03	107.15	173.42	69.78	12.98	0.77	5.92	71455.56	0.39	244.84	95.50	0.62	82.67	81.57
RIL-88	70.48	11.18	3.90	2.04	109.65	204.80	71.05	12.97	0.69	4.99	66542.51	0.40	231.03	92.49	0.63	82.47	81.42

Appendix 4. (continued).

RIL	Starch	Protein	Oil	LogAf	AntiLog AF	AF	Test Weight	Moist	Log GY	Grain Yield	Plant Pop.	EPR	Plant Height	Ear Height	ASI	Days to Silk	Days to Anthesis
RIL-91	72.20	10.46	3.28	2.03	107.15	203.05	69.75	12.98	0.75	5.62	70847.23	0.41	243.08	99.18	0.81	82.24	81.74
RIL-92	71.31	10.08	3.65	2.02	104.71	195.49	71.64	12.98	0.75	5.66	70371.57	0.42	233.35	98.15	0.94	81.61	81.57
RIL-97	71.48	10.30	3.59	2.05	112.20	184.91	71.59	12.98	0.70	5.02	65808.41	0.41	227.51	92.49	0.73	82.28	81.57
RIL-99	72.50	9.89	3.20	2.04	109.65	200.66	72.08	12.98	0.71	5.16	58579.23	0.39	222.50	88.80	0.68	81.56	80.80
RIL-101	71.21	11.23	3.50	2.05	112.20	195.91	70.51	12.97	0.71	5.24	72120.89	0.40	246.61	99.18	0.68	82.50	81.57
RIL-102	72.03	10.21	3.35	2.03	107.15	210.24	68.55	12.98	0.66	4.75	59329.02	0.41	244.54	100.88	0.79	82.48	81.87
RIL-106	71.94	11.59	2.85	2.04	109.65	202.83	72.50	12.97	0.76	5.83	71323.26	0.39	230.88	90.23	0.77	81.19	80.80
RIL-109	70.40	11.95	3.52	2.06	114.82	187.93	67.98	12.98	0.68	4.91	61372.72	0.37	240.21	88.41	0.40	82.50	80.66
RIL-111	71.36	10.88	3.39	2.07	117.49	170.29	70.60	12.99	0.72	5.31	69053.23	0.40	246.23	97.58	0.46	82.27	80.81
RIL-112	72.03	10.04	3.41	2.08	120.23	186.65	70.66	12.97	0.69	4.96	65084.32	0.43	232.46	100.39	0.75	82.05	81.58
RIL-113	71.69	10.63	3.43	2.03	107.15	200.66	71.53	12.98	0.69	4.99	71627.12	0.41	224.16	93.47	0.59	82.29	81.26
RIL-114	71.33	11.08	3.35	2.07	117.49	163.01	70.71	12.98	0.72	5.26	72969.21	0.38	235.94	89.80	0.62	82.39	81.43
RIL-115	71.08	11.21	3.53	2.03	107.15	213.63	73.54	12.97	0.74	5.55	71252.19	0.39	230.35	89.83	0.63	82.46	81.28
RIL-116	71.37	11.14	3.33	2.07	117.49	187.09	70.13	12.99	0.65	4.64	63968.07	0.39	238.38	91.46	0.72	82.68	81.88
RIL-118	70.83	11.00	3.46	2.09	123.03	190.39	71.31	12.98	0.73	5.56	62889.21	0.39	242.34	95.11	0.88	81.77	81.57
RIL-122	71.73	10.81	3.40	2.01	102.33	216.14	68.58	12.99	0.65	4.72	59541.22	0.40	239.62	95.13	0.82	82.49	81.88
RIL-123	71.21	10.79	3.53	2.06	114.82	203.57	69.20	12.97	0.72	5.30	63227.13	0.38	238.13	90.22	0.64	82.29	81.27
RIL-127	71.65	10.71	3.45	2.06	114.82	208.79	69.40	12.98	0.64	4.43	64095.53	0.38	234.81	89.19	0.88	83.26	82.65
RIL-132	71.50	10.57	3.30	2.04	109.65	195.44	71.20	12.98	0.72	5.32	65948.76	0.41	241.50	98.37	0.85	81.75	81.57
RIL-133	72.52	9.21	3.26	2.06	114.82	181.04	70.52	12.97	0.71	5.18	68553.45	0.40	232.36	93.09	0.83	82.29	81.88
RIL-134	71.49	10.31	3.61	2.05	112.20	206.19	71.03	12.99	0.69	5.01	62145.07	0.40	240.79	97.35	0.65	82.85	81.88
RIL-135	71.62	10.85	3.21	2.06	114.82	201.63	69.38	12.98	0.67	4.82	63001.07	0.43	249.67	107.30	0.76	82.31	81.58
RIL-137	71.18	10.84	3.65	2.05	112.20	201.18	73.31	12.96	0.74	5.54	73929.79	0.41	253.15	104.25	0.68	81.94	81.11
RIL-138	72.55	10.00	3.24	2.05	112.20	193.82	71.97	12.97	0.73	5.43	71195.19	0.45	235.96	106.91	0.74	82.52	81.87
RIL-140	71.40	10.34	3.70	2.04	109.65	204.79	69.87	12.99	0.64	4.54	64192.09	0.38	239.84	90.81	0.75	82.25	81.58
RIL-141	70.66	11.55	3.49	2.08	120.23	191.35	67.41	12.99	0.70	5.08	70269.42	0.37	233.14	87.18	0.56	82.15	80.81
RIL-144	71.25	11.47	3.27	2.01	102.33	199.71	72.03	12.96	0.75	5.62	71976.00	0.40	253.14	100.17	0.66	82.56	81.56
RIL-145	71.06	11.04	3.20	2.07	117.49	191.93	71.08	12.97	0.75	5.65	68600.75	0.41	249.49	101.19	0.67	81.76	80.96
RIL-147	71.00	10.93	3.49	2.03	107.15	207.31	70.22	12.98	0.74	5.63	66628.17	0.40	243.24	97.20	0.90	81.49	81.73
RIL-151	71.74	10.00	3.55	2.05	112.20	189.87	71.07	12.97	0.65	4.57	54370.00	0.37	232.19	86.13	0.93	82.01	82.05

Appendix 4. (continued).

RIL	Starch	Protein	Oil	LogAf	AntiLog AF	AF	Test Weight	Moist	Log GY	Grain Yield	Plant Pop.	EPR	Plant Height	Ear Height	ASI	Days to Silk	Days to Anthesis
RIL-153	71.67	10.64	3.22	2.06	114.82	189.25	70.42	12.97	0.72	5.35	66668.94	0.39	240.25	93.53	0.96	81.71	81.88
RIL-154	72.60	9.84	3.10	2.04	109.65	181.34	69.83	12.97	0.73	5.49	76626.30	0.42	242.58	103.87	0.75	82.35	81.71
RIL-156	72.19	9.80	3.26	2.08	120.23	159.23	69.16	12.99	0.78	6.09	69414.17	0.40	239.62	95.88	0.75	82.51	81.73
RIL-157	71.90	10.96	3.16	2.05	112.20	189.19	69.19	12.98	0.67	4.78	68977.61	0.41	237.85	97.56	0.73	82.63	81.89
RIL-162	71.97	10.99	3.18	2.04	109.65	209.13	71.84	12.98	0.67	4.74	66332.65	0.39	236.03	92.28	0.73	82.31	81.57
RIL-165	72.47	10.13	3.12	2.08	120.23	166.31	69.44	13.00	0.68	4.86	59315.34	0.37	236.88	86.54	0.67	82.86	81.88
RIL-170	70.86	10.72	3.65	2.05	112.20	201.96	70.61	12.98	0.72	5.30	68575.85	0.38	235.94	90.04	0.74	81.36	80.81
RIL-172	72.23	9.68	3.45	2.06	114.82	191.27	70.52	12.99	0.74	5.82	68155.18	0.39	238.50	93.50	0.61	83.16	82.04
RIL-173	71.90	9.82	3.54	2.06	114.82	199.04	69.17	12.98	0.72	5.35	71198.71	0.39	241.04	92.89	0.78	81.90	81.42
RIL-174	71.77	9.68	3.70	2.04	109.65	213.13	71.03	12.98	0.79	6.17	69580.54	0.40	246.71	98.19	0.66	83.16	82.20
RIL-175	71.19	10.20	3.79	2.06	114.82	195.48	67.25	12.99	0.65	4.55	70569.24	0.38	232.41	89.22	0.89	82.44	82.19
RIL-177	71.91	10.25	3.37	2.05	112.20	190.93	66.42	12.99	0.65	4.54	66259.84	0.39	240.82	94.47	0.79	82.68	82.03
RIL-178	70.91	10.60	3.85	2.04	109.65	202.65	70.29	12.98	0.66	4.67	63933.41	0.40	245.43	98.17	0.62	82.69	81.57
RIL-180	71.20	10.77	3.77	2.08	120.23	184.19	72.65	12.98	0.73	5.39	72650.14	0.40	230.75	92.28	0.72	81.72	81.11
RIL-184	71.10	11.06	3.44	2.04	109.65	191.58	69.49	12.98	0.57	3.93	67656.00	0.42	255.45	106.26	0.82	82.56	82.02
RIL-185	71.97	10.21	3.27	2.05	112.20	196.03	69.80	12.98	0.76	5.81	71535.46	0.41	236.21	96.52	0.59	82.13	80.96
RIL-186	72.03	10.07	3.43	2.08	120.23	158.42	70.43	12.98	0.69	5.07	62796.70	0.39	237.58	93.07	0.92	82.53	82.19
RIL-187	72.35	10.00	3.32	2.04	109.65	198.07	68.70	12.99	0.68	4.83	68170.71	0.43	259.87	109.99	0.90	83.07	82.79
RIL-190	71.17	10.97	3.54	2.04	109.65	177.56	71.38	12.97	0.77	5.96	69536.69	0.39	234.25	91.26	0.82	81.58	81.26
RIL-192	71.75	11.26	3.13	2.03	107.15	186.02	68.33	12.99	0.69	4.98	58989.42	0.40	243.52	98.17	0.65	83.79	82.49
RIL-195	71.00	10.75	3.67	2.05	112.20	194.14	70.42	12.98	0.75	5.60	66662.87	0.41	232.14	94.52	0.81	80.76	80.51
RIL-198	71.43	11.33	3.27	2.06	114.82	193.97	69.33	12.98	0.73	5.39	72071.76	0.40	231.75	93.48	0.69	82.04	81.28
RIL-199	72.56	9.78	3.14	2.02	104.71	208.91	71.83	12.96	0.73	5.35	68704.35	0.39	231.01	90.63	0.68	82.83	81.88
RIL-203	71.98	10.24	3.18	2.06	114.82	184.81	70.71	12.98	0.74	5.59	66233.02	0.40	241.65	96.54	0.82	82.63	82.04
RIL-205	71.97	10.15	3.31	2.02	104.71	214.43	70.66	12.98	0.70	5.06	61899.12	0.38	230.89	87.82	0.78	81.57	81.11
RIL-207	71.55	10.51	3.55	2.04	109.65	192.70	72.03	12.98	0.70	5.07	68419.04	0.39	226.42	87.80	0.85	82.46	82.03
RIL-208	71.23	10.59	3.65	2.08	120.23	180.71	69.33	12.97	0.70	5.05	70335.72	0.39	234.19	92.47	0.63	82.48	81.42
RIL-212	71.70	10.70	3.47	2.05	112.20	200.35	70.78	12.97	0.74	5.48	70662.72	0.41	234.50	96.14	0.93	83.06	81.88
RIL-216	71.53	10.76	3.47	2.03	107.15	205.20	72.44	12.97	0.70	5.08	66481.03	0.39	231.70	89.45	0.67	81.35	80.66
RIL-217	71.60	10.08	3.52	2.08	120.23	135.14	72.83	12.99	0.72	5.36	69652.23	0.38	239.10	90.86	0.82	82.11	81.73

Appendix 4. (continued).

RIL	Starch	Protein	Oil	LogAf	AntiLog AF	AF	Test Weight	Moist	Log GY	Grain Yield	Plant Pop.	EPR	Plant Height	Ear Height	ASI	Days to Silk	Days to Anthesis
RIL-220	71.66	10.39	3.40	2.04	109.65	192.99	71.73	12.98	0.78	6.00	71881.57	0.42	247.51	104.25	0.86	81.94	81.58
RIL-221	71.79	10.05	3.69	2.06	114.82	171.04	68.27	12.99	0.65	4.52	63834.75	0.40	222.12	89.21	0.63	82.61	81.73
RIL-222	71.29	10.61	3.42	2.07	117.49	160.45	68.87	12.98	0.72	5.28	59230.37	0.41	239.96	97.37	0.73	81.55	80.96
RIL-225	71.59	10.35	3.54	2.05	112.20	179.64	70.57	12.99	0.72	5.39	65654.91	0.41	244.16	100.78	0.60	82.70	81.56
RIL-226	71.30	11.06	3.31	2.05	112.20	186.57	69.85	12.99	0.69	4.98	69410.57	0.39	239.64	92.27	0.69	81.76	80.96
RIL-229	71.49	10.59	3.46	2.05	112.20	178.39	71.38	12.97	0.78	6.00	70816.18	0.40	245.87	97.55	0.63	82.84	81.73
RIL-232	70.85	11.29	3.50	2.04	109.65	194.53	67.83	12.99	0.76	5.82	73947.20	0.39	241.03	92.88	0.70	81.78	80.95
RIL-233	71.00	10.39	3.72	2.04	109.65	186.74	72.51	12.96	0.79	6.30	71504.78	0.42	239.29	99.60	0.61	82.48	81.42
RIL-237	71.47	10.49	3.46	2.03	107.15	214.01	71.67	12.98	0.75	5.65	70284.43	0.39	239.30	94.07	0.84	81.18	80.96
RIL-239	71.36	10.61	3.50	2.06	114.82	205.54	72.08	12.98	0.72	5.30	60678.16	0.38	239.92	90.83	0.72	80.95	80.65
RIL-241	70.88	10.36	3.83	2.04	109.65	179.43	73.04	12.97	0.76	5.78	63372.20	0.38	234.77	88.13	0.68	81.90	81.26
RIL-243	71.76	10.11	3.44	2.02	104.71	209.69	68.37	12.99	0.78	6.08	70408.86	0.43	237.15	103.46	0.60	81.67	80.82
RIL-244	70.97	10.92	3.63	2.03	107.15	210.08	67.46	12.98	0.75	5.62	65900.86	0.41	235.01	96.92	0.61	81.87	80.97
RIL-247	70.96	10.61	3.47	2.03	107.15	203.27	69.69	12.98	0.71	5.17	70030.08	0.38	244.98	92.89	0.72	82.13	81.42
RIL-250	71.39	10.57	3.74	2.06	114.82	200.06	70.30	12.97	0.68	4.92	64813.71	0.38	235.78	90.24	0.97	81.97	81.88
RIL-251	71.71	10.01	3.65	2.04	109.65	190.09	71.81	12.97	0.70	5.09	53623.00	0.38	243.90	92.47	0.72	81.93	81.26
RIL-255	71.41	10.59	3.52	2.04	109.65	194.64	70.32	12.98	0.71	5.32	67138.20	0.39	237.90	92.88	0.46	82.85	81.26
RIL-256	71.79	10.68	3.30	2.08	120.23	148.72	72.49	12.96	0.74	5.49	69128.34	0.39	233.63	90.84	0.72	81.91	81.27
RIL-259	70.77	11.30	3.63	2.03	107.15	210.66	74.18	12.98	0.75	5.75	64787.13	0.40	243.22	96.13	0.61	82.48	81.28
RIL-260	72.24	10.42	3.13	2.07	117.49	171.24	72.97	12.96	0.73	5.40	72171.75	0.41	245.44	101.79	0.82	82.46	82.18
RIL-261	71.21	11.30	3.34	2.05	112.20	200.62	72.09	12.98	0.68	4.80	63285.44	0.40	235.88	95.53	0.71	82.11	81.27
RIL-262	71.91	10.00	3.47	2.07	117.49	87.68	71.11	12.98	0.70	5.08	69151.70	0.38	234.15	87.81	0.70	82.13	81.41
RIL-266	71.53	10.51	3.47	2.03	107.15	198.42	71.12	12.99	0.81	6.56	71482.16	0.39	243.53	94.71	0.67	82.33	81.42
RIL-268	72.10	10.14	3.38	2.07	117.49	160.36	69.62	12.98	0.69	5.06	69543.52	0.40	248.27	99.38	0.89	82.97	82.66
RIL-269	72.63	10.20	3.03	2.03	107.15	171.91	72.01	12.98	0.76	5.87	72716.45	0.40	248.32	98.36	0.74	82.86	82.18
RIL-272	72.22	9.93	3.33	1.99	97.72	221.68	70.65	12.98	0.79	6.34	69286.98	0.42	234.33	98.81	0.82	83.83	81.87
RIL-274	72.45	10.10	2.97	2.05	112.20	204.48	70.97	12.97	0.77	5.89	73428.36	0.41	246.51	101.65	0.76	82.84	82.04
RIL-275	71.04	10.94	3.64	2.06	114.82	143.94	69.28	12.98	0.72	5.27	66133.63	0.41	236.88	97.57	0.81	82.29	81.88
RIL-276	70.98	10.31	4.01	2.03	107.15	188.88	69.61	12.99	0.74	5.53	64666.78	0.39	234.33	91.83	0.59	81.87	80.82
RIL-277	72.03	9.99	3.68	2.05	112.20	166.69	71.67	12.96	0.69	5.16	63488.50	0.40	239.74	96.14	0.81	82.88	82.33

Appendix 4. (continued).

RIL	Starch	Protein	Oil	LogAf	AntiLog AF	AF	Test Weight	Moist	Log GY	Grain Yield	Plant Pop.	EPR	Plant Height	Ear Height	ASI	Days to Silk	Days to Anthesis
RIL-279	70.87	10.98	3.70	2.06	114.82	186.13	68.55	12.98	0.72	5.29	69043.03	0.42	229.99	97.75	0.68	82.62	81.74
RIL-280	72.52	9.77	3.14	2.07	117.49	184.02	67.22	12.99	0.71	5.24	65751.23	0.38	236.39	90.41	0.78	82.28	81.73
RIL-281	72.50	9.72	3.17	2.07	117.49	188.76	68.29	12.98	0.68	4.95	64944.26	0.41	240.72	97.79	0.59	82.35	81.11
RIL-282	71.80	10.15	3.36	2.06	114.82	166.96	72.15	12.97	0.75	5.82	67258.86	0.39	241.85	92.89	0.77	82.87	82.18
RIL-283	70.81	11.16	3.49	2.05	112.20	163.36	70.65	12.99	0.75	5.66	68965.36	0.42	250.37	103.87	0.48	82.27	80.82
RIL-285	70.75	11.07	3.62	2.06	114.82	184.84	71.58	12.99	0.77	5.92	73674.36	0.39	245.91	94.90	0.71	81.93	81.12
RIL-286	71.15	10.49	3.73	2.06	114.82	134.49	71.21	12.99	0.71	5.17	64933.04	0.42	241.68	101.58	0.88	81.96	81.72
CML161/ LH195	71.65	10.36	3.34	2.05	112.20	199.96	71.40	12.98	0.73	5.44	69323.14	0.40	244.09	98.21	0.59	82.75	81.40
B73 o2/LH195	71.55	10.64	3.37	2.05	112.20	179.72	68.90	12.99	0.56	3.88	64511.58	0.41	229.99	96.15	0.69	83.28	82.32
P31B13	72.74	9.18	3.20	2.02	104.71	181.46	72.83	12.96	0.86	7.42	72610.45	0.39	241.86	94.09	0.75	80.45	80.19

Appendix 5. Phenotypic data for aflatoxin trials at Weslaco, TX during 2009.

RIL	Starch	Protein	Oil	Log Aflatoxin	AntiLog Aflatoxin	AF	Log GY	GY	Plant Pop.	EPR	Plant Height	Ear Height	ASI	Days to Silk	Days to Anthesis	Stalk Lodging	Root Lodging
RIL-2	70.60	11.48	3.88	2.33	213.80	493.32	0.69	4.95	50513.51	0.36	188.48	67.94	0.44	79.16	78.99	0.61	0.54
RIL-3	71.55	10.74	3.65	2.01	102.33	184.06	0.69	4.96	54281.92	0.36	188.34	67.46	0.45	79.47	78.93	0.58	1.79
RIL-9	71.74	10.70	3.56	2.33	213.80	440.31	0.69	4.95	51814.89	0.36	188.50	67.26	0.44	79.53	79.37	0.62	3.12
RIL-10	70.66	12.25	3.61	2.00	100.00	211.85	0.69	4.95	47798.50	0.36	188.28	67.45	0.45	78.45	77.70	0.62	1.45
RIL-11	70.89	11.18	3.90	1.99	97.72	173.33	0.69	4.95	48733.43	0.36	188.31	67.41	0.44	78.98	78.73	0.62	0.53
RIL-21	70.92	12.07	3.46	2.04	109.65	178.03	0.69	4.95	51165.22	0.36	188.28	67.51	0.45	78.74	78.15	0.62	0.52
RIL-23	70.61	12.12	3.60	2.03	107.15	185.19	0.69	4.95	54530.21	0.36	188.41	67.33	0.44	77.85	77.35	0.60	1.00
RIL-28	71.04	11.17	3.66	2.20	158.49	273.84	0.69	4.96	52480.84	0.36	188.49	67.89	0.47	79.41	78.44	0.62	0.49
RIL-31	70.91	12.27	3.36	1.86	72.44	157.38	0.69	4.95	47035.35	0.36	188.25	67.51	0.44	78.90	78.68	0.62	0.50
RIL-37	70.98	11.59	3.69	1.95	89.13	177.88	0.69	4.94	51126.13	0.36	188.63	67.78	0.44	77.94	77.66	0.62	0.67
RIL-39	71.62	10.89	3.57	2.04	109.65	253.40	0.69	4.95	48410.90	0.36	188.74	68.22	0.46	78.57	77.60	0.62	1.51
RIL-41	71.29	11.09	3.70	2.01	102.33	193.11	0.69	4.96	52884.09	0.36	188.40	67.77	0.44	78.46	78.20	0.62	0.57
RIL-42	70.43	12.28	3.75	1.99	97.72	189.79	0.69	4.95	53547.90	0.36	188.41	67.62	0.47	78.72	77.57	0.61	0.42
RIL-44	71.44	11.65	3.38	2.10	125.89	202.27	0.69	4.95	49738.40	0.36	188.67	67.85	0.44	78.54	78.36	0.58	13.00
RIL-45	71.29	11.29	3.62	2.35	223.87	494.90	0.69	4.95	53205.39	0.36	188.40	67.62	0.47	78.96	77.78	0.61	0.59
RIL-56	71.07	11.44	3.70	1.97	93.33	171.27	0.69	4.97	48409.63	0.36	188.34	67.31	0.45	79.22	78.59	0.61	1.99
RIL-57	71.19	12.26	3.41	2.12	131.83	237.69	0.69	4.94	51453.50	0.36	188.39	67.64	0.44	79.76	79.77	0.61	3.75
RIL-59	70.26	11.77	3.96	1.99	97.72	183.03	0.69	4.96	57621.75	0.36	188.59	67.78	0.45	78.32	77.67	0.62	0.70
RIL-61	70.93	11.13	3.88	2.09	123.03	204.75	0.69	4.95	47072.31	0.36	188.53	67.78	0.45	79.13	78.64	0.62	0.56
RIL-63	70.50	11.78	3.80	2.18	151.36	246.51	0.69	4.95	43654.10	0.36	188.29	67.79	0.44	78.85	78.62	0.62	0.54
RIL-64	71.12	11.04	3.91	2.05	112.20	195.48	0.69	4.95	48766.76	0.36	188.49	67.29	0.45	79.14	78.48	0.60	1.01
RIL-67	71.12	11.90	3.56	1.95	89.13	165.85	0.69	4.94	55575.74	0.36	188.46	67.49	0.44	80.50	80.64	0.61	4.39
RIL-68	70.80	11.91	3.64	2.04	109.65	190.48	0.69	4.97	49818.24	0.36	188.44	67.77	0.44	78.70	78.39	0.61	0.58
RIL-72	71.26	11.45	3.58	1.92	83.18	145.55	0.69	4.95	46688.09	0.36	188.49	67.67	0.45	79.05	78.47	0.62	1.10
RIL-75	70.45	11.73	3.90	2.13	134.90	226.17	0.69	4.96	52226.12	0.36	188.57	68.01	0.46	78.63	77.65	0.62	0.48
RIL-76	71.13	11.02	3.81	2.01	102.33	168.97	0.69	4.96	55573.40	0.36	188.47	67.68	0.45	78.40	77.76	0.61	3.95
RIL-80	70.73	11.87	3.71	2.18	151.36	286.02	0.69	4.96	44674.18	0.36	188.23	67.31	0.44	79.15	79.06	0.62	0.70
RIL-82	71.03	11.73	3.59	2.12	131.83	210.64	0.69	4.96	51850.54	0.36	188.55	67.89	0.45	78.32	77.54	0.62	1.78
RIL-85	71.51	10.89	3.70	2.21	162.18	304.19	0.69	4.95	49768.23	0.36	188.26	67.72	0.44	79.52	79.32	0.61	0.43
RIL-88	70.29	11.73	4.05	2.03	107.15	175.97	0.69	4.95	49031.81	0.36	188.60	67.77	0.45	78.69	78.05	0.62	0.66

Appendix 5. (continued).

RIL	Starch	Protein	Oil	Log Aflatoxin	AntiLog Aflatoxin	AF	Log GY	GY	Plant Pop.	EPR	Plant Height	Ear Height	ASI	Days to Silk	Days to Anthesis	Stalk Lodging	Root Lodging
RIL-91	71.07	10.61	4.05	2.08	120.23	195.56	0.69	4.95	54231.38	0.36	188.37	67.82	0.45	78.85	78.38	0.62	0.62
RIL-92	70.79	11.46	3.83	2.01	102.33	192.52	0.69	4.96	56224.31	0.36	188.51	67.65	0.45	78.58	77.93	0.62	0.50
RIL-97	71.02	11.72	3.65	2.09	123.03	204.37	0.69	4.95	43604.43	0.36	188.62	67.91	0.44	79.60	79.51	0.61	1.81
RIL-99	71.54	11.09	3.61	2.07	117.49	202.49	0.69	4.96	48093.40	0.36	188.35	67.43	0.47	79.24	78.23	0.62	0.58
RIL-101	70.41	11.41	4.11	1.81	64.57	156.20	0.69	4.96	53597.37	0.36	188.41	67.51	0.47	78.59	77.54	0.62	0.60
RIL-102	71.12	11.08	3.81	2.14	138.04	236.90	0.69	4.94	34456.00	0.36	188.33	68.05	0.44	79.67	79.65	0.62	0.51
RIL-106	71.36	11.16	3.62	1.88	75.86	170.38	0.69	4.96	50460.81	0.36	188.32	67.12	0.44	77.91	77.56	0.60	0.56
RIL-109	71.03	12.04	3.43	2.19	154.88	320.85	0.69	4.97	46730.34	0.36	188.28	67.54	0.44	78.90	78.70	0.62	0.60
RIL-111	70.77	11.75	3.80	2.11	128.82	236.72	0.69	4.94	53566.82	0.36	188.65	67.47	0.44	77.63	77.17	0.62	0.57
RIL-112	70.69	11.82	3.73	2.06	114.82	196.69	0.69	4.96	47446.01	0.36	188.09	67.51	0.45	78.94	78.38	0.62	0.59
RIL-113	70.89	11.83	3.66	2.08	120.23	202.00	0.69	4.96	50129.00	0.36	188.29	67.72	0.44	78.87	78.55	0.62	0.47
RIL-114	71.15	11.96	3.61	2.04	109.65	179.69	0.69	4.96	53879.74	0.36	188.57	68.09	0.44	79.47	79.29	0.61	1.78
RIL-115	70.59	12.33	3.62	1.82	66.07	135.73	0.69	4.95	51460.59	0.36	188.34	68.03	0.45	78.54	77.77	0.62	0.46
RIL-116	71.10	11.90	3.52	1.93	85.11	180.12	0.69	4.96	50159.16	0.36	188.36	67.56	0.44	79.40	79.21	0.62	0.59
RIL-118	70.39	12.39	3.68	2.02	104.71	185.11	0.69	4.95	45018.55	0.36	188.05	67.59	0.45	78.40	77.77	0.59	0.48
RIL-122	70.99	11.68	3.66	1.99	97.72	159.73	0.69	4.96	39241.55	0.36	188.17	67.09	0.44	78.93	78.61	0.62	1.10
RIL-123	70.54	12.06	3.73	2.01	102.33	178.85	0.68	4.94	43649.45	0.36	188.48	68.02	0.45	78.60	77.88	0.61	0.50
RIL-127	71.01	11.31	3.75	2.04	109.65	184.42	0.69	4.96	35472.00	0.36	188.77	67.59	0.44	80.07	80.18	0.62	0.65
RIL-132	70.64	12.37	3.57	2.03	107.15	171.41	0.69	4.97	45338.77	0.36	188.39	67.22	0.44	78.56	78.40	0.60	8.86
RIL-133	71.36	10.85	3.74	1.98	95.50	157.73	0.69	4.95	51471.48	0.36	188.48	67.65	0.45	78.36	77.77	0.61	0.56
RIL-134	71.15	11.43	3.72	2.05	112.20	182.94	0.69	4.95	44353.85	0.36	188.42	67.70	0.44	79.03	78.90	0.61	0.54
RIL-135	70.30	12.97	3.54	2.04	109.65	187.96	0.69	4.95	44339.68	0.36	188.27	67.90	0.48	79.31	77.96	0.62	0.57
RIL-137	70.18	11.84	4.04	2.13	134.90	226.23	0.69	4.97	53944.70	0.36	188.12	67.30	0.44	79.05	79.02	0.62	2.71
RIL-138	71.72	10.64	3.75	2.11	128.82	211.30	0.69	4.95	54561.27	0.36	188.43	67.89	0.47	78.91	77.81	0.62	0.56
RIL-140	71.05	11.48	3.84	1.89	77.62	245.76	0.69	4.94	45665.09	0.36	188.55	67.62	0.44	78.48	78.00	0.62	0.53
RIL-141	71.12	11.82	3.55	2.08	120.23	193.11	0.69	4.94	51167.40	0.36	188.33	67.98	0.45	79.08	78.47	0.62	0.55
RIL-144	70.27	12.00	3.92	2.04	109.65	209.35	0.69	4.95	52883.29	0.36	188.41	67.19	0.45	78.29	77.62	0.62	0.98
RIL-145	70.55	11.62	3.80	2.10	125.89	218.70	0.69	4.96	49807.77	0.36	188.19	67.41	0.44	77.75	77.41	0.61	0.60
RIL-147	70.43	12.16	3.81	2.08	120.23	196.07	0.69	4.95	49433.62	0.36	188.54	67.48	0.45	79.45	78.90	0.61	0.49
RIL-151	71.31	10.94	3.77	2.12	131.83	252.40	0.69	4.95	40256.99	0.36	188.62	67.51	0.45	78.95	78.33	0.62	0.50

Appendix 5. (continued).

RIL	Starch	Protein	Oil	Log Aflatoxin	AntiLog Aflatoxin	AF	Log GY	GY	Plant Pop.	EPR	Plant Height	Ear Height	ASI	Days to Silk	Days to Anthesis	Stalk Lodging	Root Lodging
RIL-153	70.71	11.90	3.68	2.08	120.23	259.37	0.69	4.94	52852.02	0.36	188.46	67.43	0.45	79.01	78.32	0.62	1.32
RIL-154	71.60	10.58	3.72	2.16	144.54	242.25	0.69	4.96	53555.80	0.36	188.51	67.41	0.45	79.34	78.87	0.62	0.49
RIL-156	71.30	11.10	3.70	2.10	125.89	185.00	0.69	4.96	49475.83	0.36	188.24	67.83	0.45	79.57	79.01	0.62	0.57
RIL-157	71.07	10.87	3.84	2.15	141.25	226.25	0.69	4.98	44367.33	0.36	188.48	67.63	0.44	78.92	78.73	0.62	0.59
RIL-162	70.92	11.99	3.68	2.10	125.89	221.16	0.69	4.94	53536.94	0.36	188.54	67.84	0.46	79.52	78.67	0.62	0.53
RIL-165	71.79	10.57	3.68	2.21	162.18	342.49	0.69	4.95	43980.44	0.36	188.38	67.93	0.44	78.17	77.90	0.62	1.24
RIL-170	70.34	11.74	3.91	2.27	186.21	447.58	0.69	4.96	50083.80	0.36	188.42	67.47	0.44	78.35	78.05	0.62	0.91
RIL-172	71.15	11.08	3.81	2.02	104.71	280.83	0.69	4.95	52166.21	0.36	188.77	67.88	0.44	79.35	79.29	0.62	0.54
RIL-173	70.91	11.52	3.72	1.98	95.50	191.22	0.69	4.95	49813.85	0.36	188.37	68.08	0.45	79.05	78.40	0.62	0.58
RIL-174	71.25	10.97	3.90	1.98	95.50	179.58	0.69	4.97	48791.64	0.36	188.10	67.57	0.44	80.12	80.18	0.62	0.52
RIL-175	70.66	11.52	3.90	2.01	102.33	166.99	0.69	4.95	53246.95	0.36	188.65	68.29	0.44	80.11	80.15	0.60	0.56
RIL-177	71.05	11.24	3.75	2.00	100.00	186.83	0.69	4.95	50166.84	0.36	188.51	67.50	0.46	79.85	79.07	0.62	0.42
RIL-178	69.76	12.82	3.84	2.05	112.20	208.38	0.69	4.95	48121.01	0.36	188.34	67.67	0.45	79.57	79.05	0.62	0.59
RIL-180	70.21	12.05	4.06	2.01	102.33	197.04	0.69	4.95	52157.34	0.36	188.64	67.83	0.45	79.10	78.55	0.62	1.83
RIL-184	70.37	12.35	3.71	2.01	102.33	179.28	0.69	4.95	38529.00	0.36	188.10	67.48	0.44	79.90	79.87	0.62	0.52
RIL-185	71.68	11.09	3.55	2.14	138.04	226.23	0.69	4.94	52155.54	0.36	188.12	67.76	0.47	79.36	78.30	0.62	2.75
RIL-186	71.08	11.70	3.67	2.06	114.82	194.14	0.69	4.94	48817.47	0.36	188.48	67.34	0.45	79.52	79.02	0.62	0.46
RIL-187	70.98	11.28	3.90	2.05	112.20	193.09	0.69	4.96	49416.03	0.36	188.37	67.21	0.45	80.10	79.76	0.62	2.87
RIL-190	70.53	11.55	3.96	2.05	112.20	177.02	0.69	4.95	50399.39	0.36	188.52	67.75	0.44	79.06	78.79	0.61	2.18
RIL-192	70.97	12.45	3.36	1.91	81.28	177.25	0.69	4.96	41235.92	0.36	188.22	68.09	0.46	79.72	78.92	0.62	0.57
RIL-195	70.80	11.54	3.88	2.14	138.04	370.05	0.69	4.95	48733.18	0.36	188.28	67.42	0.45	78.40	77.74	0.62	0.54
RIL-198	70.97	11.58	3.79	1.89	77.62	135.85	0.69	4.95	50829.91	0.36	188.54	67.96	0.44	78.30	77.97	0.59	0.43
RIL-199	71.84	10.70	3.55	2.03	107.15	183.71	0.69	4.96	53477.45	0.36	188.26	67.91	0.44	79.35	79.07	0.60	0.46
RIL-203	71.30	11.60	3.51	2.11	128.82	211.45	0.69	4.96	50813.07	0.36	188.58	67.97	0.45	79.93	79.46	0.61	0.58
RIL-205	71.46	11.22	3.56	1.82	66.07	160.57	0.69	4.95	46392.83	0.36	188.41	67.65	0.45	78.48	77.81	0.60	4.20
RIL-207	71.01	11.31	3.83	2.03	107.15	189.39	0.69	4.96	52492.57	0.36	188.50	67.22	0.44	77.92	77.67	0.58	1.44
RIL-208	70.42	12.12	3.78	2.13	134.90	228.36	0.69	4.95	49421.53	0.36	188.31	67.74	0.44	79.32	79.28	0.62	0.55
RIL-212	71.26	11.18	3.78	1.84	69.18	184.30	0.69	4.95	52579.44	0.36	188.75	67.65	0.44	80.29	80.46	0.62	0.50
RIL-216	71.08	11.27	3.83	1.98	95.50	171.86	0.69	4.95	49475.42	0.36	188.52	67.43	0.44	78.72	78.51	0.62	0.54
RIL-217	70.97	11.33	3.81	2.12	131.83	223.10	0.69	4.95	50446.17	0.36	188.35	67.72	0.47	79.55	78.60	0.62	1.56

Appendix 5. (continued).

RIL	Starch	Protein	Oil	Log Aflatoxin	AntiLog Aflatoxin	AF	Log GY	GY	Plant Pop.	EPR	Plant Height	Ear Height	ASI	Days to Silk	Days to Anthesis	Stalk Lodging	Root Lodging
RIL-220	71.07	11.19	3.73	2.09	123.03	204.85	0.69	4.96	48776.29	0.36	188.43	67.81	0.46	78.85	77.88	0.62	0.74
RIL-221	71.07	11.33	3.78	2.01	102.33	188.22	0.69	4.95	39870.75	0.36	188.57	67.92	0.45	80.28	79.85	0.62	0.49
RIL-222	70.82	12.14	3.47	2.16	144.54	234.76	0.69	4.97	38536.00	0.36	188.40	67.57	0.44	79.59	79.43	0.62	0.63
RIL-225	71.13	11.45	3.76	2.06	114.82	190.75	0.69	4.96	43358.12	0.36	188.33	67.75	0.44	79.21	79.15	0.62	0.46
RIL-226	70.73	11.68	3.79	2.08	120.23	201.63	0.69	4.95	51194.83	0.36	188.47	67.56	0.44	78.64	78.26	0.62	1.00
RIL-229	70.77	11.16	3.77	1.91	81.28	164.67	0.69	4.96	55250.97	0.36	188.51	67.75	0.44	79.27	79.28	0.62	0.50
RIL-232	70.78	11.95	3.73	2.04	109.65	186.63	0.69	4.95	45365.14	0.36	187.65	67.13	0.44	79.76	79.74	0.60	0.52
RIL-233	70.59	11.54	3.83	1.90	79.43	201.06	0.69	4.95	51172.34	0.36	188.60	67.26	0.44	77.90	77.57	0.62	1.36
RIL-237	70.21	12.20	3.87	1.86	72.44	175.63	0.69	4.96	54874.73	0.36	188.26	67.05	0.44	78.19	77.89	0.59	0.55
RIL-239	71.22	10.78	3.92	1.87	74.13	203.52	0.69	4.96	48119.70	0.36	188.54	67.66	0.45	79.23	78.57	0.61	3.40
RIL-241	70.47	11.36	4.06	2.01	102.33	188.76	0.69	4.96	44684.62	0.36	188.55	67.89	0.46	78.83	77.92	0.62	4.39
RIL-243	71.29	11.12	3.65	2.20	158.49	348.07	0.69	4.96	52875.22	0.36	188.44	67.69	0.47	78.43	77.26	0.62	0.50
RIL-244	70.48	11.79	3.90	2.19	154.88	278.40	0.69	4.95	51841.92	0.36	188.47	67.78	0.45	78.70	78.04	0.61	0.54
RIL-247	69.67	13.05	3.82	2.04	109.65	201.11	0.69	4.96	51851.76	0.36	188.23	66.90	0.45	80.23	79.87	0.62	0.61
RIL-250	70.48	11.82	3.96	1.99	97.72	179.56	0.69	4.96	49833.22	0.36	188.39	67.50	0.44	79.22	79.09	0.62	0.47
RIL-251	71.12	11.39	3.76	2.23	169.82	326.35	0.69	4.95	39912.62	0.36	188.48	67.84	0.45	79.22	78.71	0.62	0.54
RIL-255	70.56	12.38	3.65	2.00	100.00	174.47	0.69	4.96	51120.30	0.36	188.36	67.81	0.44	79.94	79.96	0.62	0.59
RIL-256	70.76	12.00	3.66	2.11	128.82	251.58	0.69	4.96	46733.16	0.36	188.43	67.86	0.46	78.73	77.71	0.61	0.65
RIL-259	70.93	11.69	3.75	1.90	79.43	164.33	0.69	4.96	51130.49	0.36	188.36	67.61	0.44	79.01	78.81	0.61	1.47
RIL-260	71.29	11.43	3.52	2.23	169.82	414.87	0.69	4.95	50808.46	0.36	188.64	67.97	0.45	78.59	77.89	0.62	2.20
RIL-261	70.98	11.74	3.70	2.01	102.33	200.44	0.69	4.96	44002.33	0.36	188.57	68.12	0.44	78.18	77.89	0.61	0.43
RIL-262	70.57	11.85	3.82	2.06	114.82	191.22	0.69	4.96	50837.35	0.36	188.51	68.02	0.44	78.89	77.97	0.62	0.49
RIL-266	70.45	12.22	3.70	2.22	165.96	376.00	0.69	4.96	53557.30	0.36	188.36	67.95	0.45	78.74	78.18	0.61	0.50
RIL-268	70.68	12.15	3.58	2.25	177.83	351.04	0.69	4.96	51507.84	0.36	188.04	67.23	0.44	80.12	80.22	0.62	2.13
RIL-269	71.85	11.07	3.46	1.93	85.11	159.08	0.69	4.96	57974.47	0.36	188.35	67.44	0.45	78.67	78.12	0.62	0.54
RIL-272	71.33	11.36	3.67	2.15	141.25	279.17	0.69	4.94	46041.54	0.36	188.66	67.43	0.45	78.99	78.43	0.62	0.47
RIL-274	71.49	11.42	3.42	2.01	102.33	179.55	0.69	4.96	53572.18	0.36	188.82	67.89	0.44	78.50	78.16	0.62	0.50
RIL-275	70.45	12.18	3.87	2.12	131.83	222.98	0.69	4.95	49811.67	0.36	188.48	67.89	0.44	79.22	79.00	0.62	2.39
RIL-276	70.44	11.33	4.23	2.14	138.04	286.87	0.69	4.96	50834.65	0.36	188.39	67.50	0.44	78.58	78.41	0.60	0.52
RIL-277	70.09	12.57	3.81	2.28	190.55	600.43	0.69	4.96	38525.00	0.36	188.72	67.94	0.44	79.31	79.27	0.62	1.22

Appendix 5. (continued).

RIL	**Starch**	**Protein**	**Oil**	**Log Aflatoxin**	**AntiLog Aflatoxin**	**AF**	**Log GY**	**GY**	**Plant Pop.**	**EPR**	**Plant Height**	**Ear Height**	**ASI**	**Days to Silk**	**Days to Anthesis**	**Stalk Lodging**	**Root Lodging**
RIL-279	70.34	12.17	3.78	2.09	123.03	420.93	0.69	4.97	46030.55	0.36	188.51	67.64	0.45	79.03	78.53	0.61	1.69
RIL-280	71.62	11.08	3.51	1.89	77.62	164.99	0.69	4.97	51480.60	0.36	188.40	67.98	0.45	79.79	79.23	0.62	0.55
RIL-281	71.67	10.71	3.66	2.21	162.18	302.08	0.69	4.95	38918.00	0.36	188.34	67.41	0.44	79.18	79.18	0.62	0.46
RIL-282	71.20	10.89	3.82	2.05	112.20	184.08	0.69	4.97	50475.83	0.36	188.11	67.21	0.45	79.07	78.53	0.61	0.44
RIL-283	70.17	11.91	4.00	2.04	109.65	183.86	0.69	4.95	53879.90	0.36	188.28	67.03	0.45	79.44	79.06	0.61	4.32
RIL-285	69.99	12.30	3.92	2.09	123.03	195.58	0.69	4.96	53532.46	0.36	188.62	67.60	0.45	78.14	77.35	0.61	2.02
RIL-286	70.32	12.05	3.86	2.10	125.89	206.24	0.69	4.95	41297.29	0.36	188.48	67.43	0.47	79.51	78.63	0.62	1.10
CML161/ LH195	71.13	10.81	3.92	1.91	81.28	143.39	0.69	4.95	56263.47	0.36	188.04	67.03	0.44	77.88	77.44	0.61	0.51
B73 o2/LH195	70.99	11.90	3.62	2.11	128.82	211.19	0.69	4.96	43956.14	0.36	188.64	67.68	0.44	79.40	79.28	0.62	0.49
P31B13	72.64	9.60	3.53	2.26	181.97	495.47	0.69	4.95	51164.27	0.36	188.51	67.32	0.45	79.19	78.73	0.62	0.49

Appendix 6. QTL detected during 2008 across three Texas environments.

Trait	Chromosome	Marker	Position	LOD Score	Additive Affect	R2	LOD 2-left2	Lod2-right
2008 Starch	1	5	34.5	4.1906	0.1616	0.116	29.5	40.6
2008 Starch	8	3	28.6	3.0397	-0.1554	0.1068	20.6	36.6
2008 Starch	9	6	70.7	2.9843	0.1343	0.0794	55.7	73.9
2008 Protein	8	5	39.5	4.0748	0.1437	0.1184	24.1	49.0
2008 Protein	9	10	125.9	3.2201	-0.1547	0.1398	114.1	136.0
2008 Oil	1	5	34.5	8.109	-0.0918	0.1942	30.4	39.1
2008 Oil	1	7	48.9	3.84	-0.0825	0.156	42.9	63.1
2008 Oil	1	21	193.4	4.4814	0.0652	0.0975	183.4	198.2
2008 Oil	1	22	204.2	3.7988	0.072	0.1179	198.2	216.4
2008 Oil	6	8	63.6	3.1384	-0.0536	0.0664	52.4	72.2
2008 Oil	7	7	73.2	4.0553	0.0699	0.1135	66.5	79.4
2008 Oil	7	9	83.4	3.2387	0.0621	0.0892	79.4	91.5
2008 TNHA	3	13	114.6	5.6121	-0.0775	0.141	113.8	118.6
2008 TNHA	3	15	126.3	6.7343	-0.0879	0.1743	123.7	130.4
2008 TNHA	3	18	140.4	6.9536	-0.1064	0.2648	130.4	153.9
2008 TNHA	4	13	95.4	3.6377	-0.0687	0.1096	89.5	105.9
2008 TNHA	4	15	109.1	3.2671	-0.0587	0.0768	105.9	121.1
2008 TNHA	5	3	42.4	2.93	-0.0534	0.0682	16.6	57.0
2008 TNHA	9	7	83.9	4.5895	-0.0744	0.1356	73.4	90.6
2008 TNHA	9	8	94.6	4.4858	-0.0701	0.1198	90.6	101.0
2008 EHCM	5	2	30.6	3.3472	-1.2156	0.1646	10.4	42.4
2008 EHCM	5	4	50.8	5.5047	-1.244	0.1603	50.2	57.7
2008 EHCM	9	1	2	3.7107	-0.9404	0.0971	0.0	22.9
2008 PHCM	1	9	72.9	3.9923	-1.6805	0.0919	68.3	82.9
2008 PHCM	2	15	177	4.5909	-1.746	0.0982	176.7	187.4
2008 PHCM	5	3	42.4	4.6617	-1.7683	0.0992	21.7	48.8
2008 PHCM	5	4	54.8	4.8885	-2.0846	0.1347	48.8	58.8

Appendix 6. (continued).

Trait	Chromosome	Marker	Position	LOD Score	Additive Affect	R2	LOD 2-left2	Lod2-right
2008 PHCM	9	3	15.6	3.1536	-1.8374	0.1157	7.6	33.6
2008 EPR	7	16	148.3	3.0739	0.0008	0.081	136.2	164.2
2008 EPR	9	8	90.6	4.9064	-0.0012	0.1306	89.9	97.3
2008 ASI	8	6	50.6	2.517	0.0243	0.0683	39.0	65.0
2008 ASI	9	4	40.8	3.4555	-0.0342	0.1531	15.1	52.5
2008 ASI	10	5	39.4	3.7897	0.0299	0.1166	26.9	47.7
2008 FF	8	5	45.5	4.7042	0.2443	0.1432	39.3	57.7
2008 FF	9	7	73.9	5.7149	0.2419	0.1417	65.3	85.0
2008 AF	1	8	70.3	2.8699	32.4943	0.0832	46.7	83.0
2008 LogAF	4	12	88.5	3.854	-0.0801	0.1131	81.3	95.8
2008 LogAF	4	15	109.1	3.6651	0.0731	0.0958	105.6	121.3
2008 LogAF	9	6	72.7	3.2381	0.0625	0.0886	56.0	89.7

Appendix 7. Quantitative Trait Loci detected during 2009 across two Texas environments.

Trait	Chromosome	Marker	Position	LOD Score	Additive Affect	R2	LOD2-left2,	Lod2-right
2009 Starch	5	12	159.7	4.094	0.1457	0.1194	148.1	164.1
2009 Starch	8	5	41.5	3.2572	-0.132	0.0918	30.1	50.6
2009 Protein	5	13	162	4.1834	-0.1319	0.1204	148.3	164.2
2009 Protein	6	2	20.6	2.4365	-0.1027	0.0657	9.6	28.8
2009 Protein	8	5	43.5	5.4556	0.1601	0.1828	39.0	55.8
2009 Protein	9	1	0.0	3.7984	-0.1238	0.1076	0.0	3.0
2009 Protein	9	3	11.6	2.849	-0.1309	0.1198	3.0	28.5
2009 OIL	1	4	33.3	3.0585	-0.0459	0.0907	20.0	40.8
2009 OIL	3	7	61.4	5.1977	0.0672	0.1682	54.7	72.1
2009 OIL	5	1	4.0	3.3458	0.0527	0.1059	0.0	10.6
2009 OIL	5	2	24.6	3.5228	0.0616	0.1584	10.6	52.1
2009 MS	2	13	146.8	3.5327	-0.0209	0.12	133.0	161.5
2009 LogTNHA	9	13	148	3.1248	0.0018	0.1139	139.2	166.0
2009 TNHA	1	20	186	2.9998	0.017	0.0861	172.6	192.5
2009 TNHA	2	8	91.5	3.0711	0.0201	0.1231	85.7	109.3
2009 EHCM	5	9	129.4	3.3626	-0.3737	0.0944	119.4	135.1
2009 PHCM	1	20	190	6.0042	-0.7848	0.1787	185.9	193.4
2009 PHCM	1	22	198.2	6.7562	-0.7665	0.1683	193.4	207.9
2009 PHCM	6	16	158.9	4.4615	-0.6112	0.1051	150.8	160.9
2009 ASI	4	7	62.3	2.9383	-0.0223	0.0947	54.9	69.9
2009 FF	1	24	244	3.4489	0.1793	0.1269	227.6	254.2
2009 FF	9	6	72.7	4.7228	0.1942	0.1498	60.6	85.5
2009 MF	9	7	77.9	3.9206	0.2529	0.1615	70.7	88.1
2009 AF	8	2	15.3	2.7618	10.3201	0.093	0.0	36.9

Appendix 8 QTL detected across five Texas environments during 2008 and 2009.

Trait	Chromosome	Marker	Position	LOD Score	Additive Affect	R2	LOD 2-left2	Lod2-right
Across Starch	1	5	36.5	3.3058	0.1075	0.0977	30.0	58.2
Across Starch	5	3	44.4	3.6897	-0.1103	0.1	27.3	56.6
Across Starch	6	15	153.3	3.9642	0.1292	0.1427	142.4	160.9
Across Starch	8	1	4	4.5599	-0.1272	0.14	0.0	15.1
Across OIL	1	3	26.4	4.1872	-0.0553	0.141	20.1	29.3
Across OIL	1	5	34.5	6.5446	-0.0625	0.1778	32.3	38.1
Across OIL	5	3	44.4	2.6606	0.039	0.0662	0.0	57.9
Across OIL	5	11	155.8	2.9982	-0.0408	0.0763	143.3	163.9
Across OIL	9	7	73.9	3.2982	-0.0433	0.0826	67.3	90
Across LogTNHA	2	5	54.5	4.7199	-0.0073	0.1285	38.6	65.3
Across LogTNHA	3	7	65.4	3.558	-0.0081	0.1351	59.4	67.4
Across LogTNHA	3	18	134.4	5.328	-0.0081	0.1476	124.7	149.1
Across LogTNHA	3	20	176.2	3.0475	-0.0061	0.0906	158.0	191.4
Across LogTNHA	9	7	77.9	4.8754	-0.0085	0.1664	64.6	88.4
Across EHCM	5	4	48.8	2.6344	-0.5965	0.0707	42.4	59.9
Across PHCM	1	10	89.4	3.3148	-1.2715	0.0909	85.2	95
Across PHCM	1	13	103.6	3.8155	-1.382	0.1049	95.0	111.6
Across PHCM	1	20	188	3.6265	-1.307	0.0912	185.8	193.4
Across PHCM	1	22	198.2	3.6202	-1.2465	0.0801	193.4	213.1
Across PHCM	2	13	154.8	2.8683	-1.3177	0.0954	140.1	167.7
Across PHCM	2	15	177	3.4005	-1.1851	0.0766	167.7	189.5
Across PHCM	5	2	40.6	2.8688	-1.1593	0.0712	10.6	48.8
Across PHCM	9	1	0.0	3.3089	-1.1605	0.0711	0.0	7.6
Across FF	8	5	43.5	3.2258	0.165	0.0951	33.2	50.1
Across FF	9	7	75.9	8.5552	0.262	0.2465	64.5	83.7
Across LogAF	1	9	70.9	3.0003	0.0245	0.0887	52.9	81.3
Across LogAF	3	8	68.9	3.2433	0.0291	0.0969	62.7	79.3
Across AF	3	8	68.9	3.1059	19.9138	0.0877	62.4	79.8
Across AF	4	15	109.1	2.8738	17.2366	0.0783	97.0	122.1

VITA

Name:	Kerry Lucas Mayfield
Education:	B.S., Agronomic, Texas Tech University, 1997 M.S., Plant Breeding, Texas A&M University, 2006 Ph.D., Plant Breeding, Texas A&M University, 2011
Email Addresses:	kmayfield@dow.com
Permanent Address:	Triumph Seed Co P.O. Box 1050 Ralls, TX 79357